

MAXIMIZING THE BENEFITS OF COURTROOM POES IN DESIGN DECISION
SUPPORT AND ACADEMIC INQUIRY THROUGH A UNIFIED CONCEPTUAL
MODEL

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Presented to
The Academic Faculty

By

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dedicated to Naina and Sipra whose affection kept me going...

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SUMMARY

Post-occupancy evaluations represent an important missed opportunity. While POEs are often used to inform design guides, and to support facility management, they are less commonly used to support design decision-making. While there are several technical, methodological, and cultural impediments to the ongoing use of POE results in design, characteristics of POE data and data structure is an important, and often overlooked, impediment. Some evaluators have attempted to resolve this problem by involving actively as consultants in design teams or involving users, such as ‘Placemaking’ or ‘Process Architecture’. Recent advances in conceptual data modeling provide another strategy to interface POE findings and design decision-making. This thesis uses EXPRESS modeling language to develop a conceptual data structure for POE data, and integrate POE data with as-built building descriptions. While this effort has the potential to develop an improved way to structure POE data and make it more useful, it is also an extension of ISO-STEP. This study develops a data structure based on post-occupancy evaluations of state and federal trial courtrooms conducted by the researcher. Thirty-one courtrooms were evaluated, resulting in usable data from 93 courtroom users in 26 courtrooms. An EXPRESS-G schema was developed and was translated into a relational database for holding data and running queries. The investigator illustrated a range of query-generated outcomes to support decision-making during design and design review. Such outcomes include exploring existing courtrooms, comprehending the types of design decisions implemented across federal and state courtrooms, identifying design

decisions that have been rated favorably or otherwise by courtroom users, rating design decisions based on evaluation data from existing courtrooms, and predicting a designed environment's supportiveness to task performance. Further, multivariate analysis of the POE data provides the first scientific investigation of courtrooms as work settings. Finally, eight key performance indicators of courtrooms were developed based on the POE data.

Chapter 1

Overview

Post-occupancy evaluations (POEs) represent an important missed opportunity. While POEs are often used to inform design guides (Kernohan, Gray, Daish, & Joiner, 1992), and to support facility management (Zimring, Wineman, & Carpman, 1988), they are much less commonly used to support design decision-making (Kernohan et al., 1992; Zimring, 2001). This is a particular problem because little design research otherwise goes on within architecture. POEs could provide a significant aid to improving building performance through design.

While there are several technical, methodological, and cultural impediments to the ongoing use of POE results in design, characteristics of POE data and data structure are an important, and often overlooked, impediment. Design is fundamentally about linking decisions about the form of buildings to a desired set of technical or human outcomes. Because of the non-linear and exploratory nature of design, it is difficult to predict which relationships will be most useful to designers. However, few POEs are represented in ways that allow end-users to explore patterns across studies or between different kinds of variables, such as building descriptions, building performance and user response. Most POEs are available as printed documents, and it is very difficult to access specific information relevant to a particular design decision. Even when data are represented in databases it is often difficult for the user of the information to go beyond simple profiles of results and it is particularly difficult to assimilate data from multiple studies that deal

with different sets of variables, or to represent complex relationships between data types or between concepts and data.

Some evaluators have attempted to resolve this problem by involving evaluators actively as consultants in design teams (Preiser, 1996) or involving users, such as ‘Placemaking’ (Schneekloth & Shibley, 1995) or ‘Process Architecture’ (Horgen, Joroff, Porter, & Schon, 1999). In these practices individuals or groups use expertise and social processes to identify patterns of results, note trends and identify new relationships. This allows the design team to explore past POE results in rich and complex ways, but requires accessible POE data and active participation by evaluators in design.

Recent advances in conceptual data modeling provide another strategy to interface POE findings and design decision-making. Starting in the 1980s in the aerospace industry, and more recently in the building industry, researchers have sought to create comprehensive representations of building data that permit seamless exchange of data between different systems (Eastman, 1999). In particular, the EXPRESS data modeling language in ISO-STEP provides a unique approach to integrate as-built descriptions of buildings with performance data coming from POEs. EXPRESS addresses the impediments faced in traditional data representations. EXPRESS is an object-oriented data modeling language. This means that abstract concepts/ constructs and complex relationships between entities that, hitherto, could not be meaningfully represented in conventional POE data storage mediums, can be included in a holistic representation. The building blocks of the modeling language are schemas that allow hierarchical organization of data, as well as

nested schemas. Such a structure resembles the phenomena and constructs dealt with in POE research, and offer a richer medium to hold data. Data from multiple studies can be integrated or added without losing the comprehensibility of the model.

This thesis uses EXPRESS to develop a conceptual data structure for POE data, and integrate POE data with as-built building descriptions. While this effort has the potential to develop an improved way to structure POE data and make it more useful, it is also an extension of ISO-STEP. ISO-STEP has typically been used for structuring quantitative as-built building descriptions. It is a challenge to include softer user responses in the data structure.

This study develops a data structure based on post-occupancy evaluations of state and federal trial courtrooms conducted by the researcher. Trial courtrooms were chosen for both theoretical and practical reasons. A courtroom is a relatively constrained space, and hence is practical to measure, yet has a complex range of activities and tasks. It has a rich mix of instrumental and symbolic function that is characteristic of many POEs. Also, the researcher was quite knowledgeable about courtrooms and had good contacts among the courthouse community.

The researcher created a POE protocol by:

- 1) Conducting literature review, interviews and observations to establish the key tasks for each of the roles in courtrooms.

- 2) Creating a model linking physical parameters such as lighting, acoustics and physical dimensions to support of the key tasks.
- 3) Developing a user questionnaire focusing on the user's evaluation of how the setting supported their tasks.
- 4) Developing procedures for physical measurements of the courtrooms.
- 5) Pre-testing and refining the protocol.

Thirty-one courtrooms were evaluated, resulting in usable data from 93 courtroom users in 26 courtrooms. An EXPRESS-G schema was developed and was translated into a relational database for holding data and running queries. The investigator illustrated a range of query-generated outcomes to support decision-making during design and design review. Such outcomes include exploring existing courtrooms, comprehending the types of design decisions implemented across federal and state courtrooms, identifying design decisions that have been rated favorably or otherwise by courtroom users, rating design decisions based on evaluation data from existing courtrooms, and predicting a designed environment's supportiveness to task performance.

While this study is primarily methodological in nature, and focuses on developing a modality that would address concerns expressed in Environment and Behavior studies (EB) literature, the space type (courtrooms) used in the study expands existing knowledge on courtrooms as work settings. Studies on courtrooms are not widely available in academic publications. Most studies on interactions between users and their environments (in building engineering as well as in EB) have been conducted in

contrived experimental settings, involving contrived tasks that have little similarities with real-life situations in courtrooms. Available reports on field studies are focused on industrial environments, schools, and offices. Studies on offices and classrooms hold promise insofar as they are similar in certain ways to courtrooms. Courtrooms, it could be argued, are similar to offices since they constitute a type of work setting. The physical settings of courtrooms and the types of tasks performed there are also similar, in some ways, to classrooms.

Courtrooms, however, pose a unique behavior setting, and the differences between courtrooms and other settings are considerable. Courtroom users do not use the space on a day-to-day basis. For the frequent users (the judges, court deputies, reporters, attorneys), courtroom is not the only assigned workspace. All of them also have a separate space that they use regularly for longer periods, with the courtroom being a setting for intermittent operations. Activities in a courtroom very strongly impact the life and liberty of the parties involved. There is a pressure to arrive at judgments within limited periods of time (for criminal cases). The setting is open to public, and hence, involves an added necessity to orchestrate the symbolism associated with a democratic government, the rule of law, the role of the citizens, and state-citizen relationship. Few other behavior settings involve as much complexity as a courtroom, which includes a combination of the seriousness of an aircraft cockpit decision, a concern towards productivity, and the necessity to portray symbolism. Thus, all the studies published on contrived industrial-military settings and field studies on offices and classrooms, while informative, would be viewed skeptically if adopted for decision making in courtroom

design. From such a viewpoint, this study provides an in-depth understanding of courtrooms as settings of a unique nature.

In view of the limited knowledge on courtrooms in existing literature, the dissertation proceeds, as the first step, with a working understanding of courtrooms. An exploratory study of courtrooms was conducted to develop a better comprehension of courtroom functions (chapter 4). Physical and environmental factors that could possibly influence the performance of courtroom tasks were identified through a review of existing literature in building engineering and psychology (chapter 5).

Findings from the exploratory study on courtrooms and literature review of possible factors influencing courtroom tasks was used to develop a POE study of federal and state courtrooms in the United States (chapter 6). In all, the investigator visited 31 courtrooms as part of the POE study. User survey questionnaires were distributed during the visits to the judge, deputy/clerk, reporter, attorney, and security staff in each courthouse. Ninety three user surveys from 26 courtrooms were obtained by mail. In addition, as-built physical and environmental data was also collected from the courtrooms during the site visits. The as-built data types and the user data were modeled using EXPRESS-G to create an integrated semantic structure that holds both as-built building data as well as user and evaluation data (chapter 7). A relational database reflecting the model was developed using MS ACCESS software.

The thesis envisages two types of outcomes resulting from the modeling of courtroom POE data in an integrated data structure: decision support at the early design and design review phases (chapter 8), and outcomes from processed data (chapter 9). Six types of scenarios are explored in the area of design decision support, ranging from precedence analysis to evaluating decisions based on known evaluation data from similar settings. Outcomes from processed data include a detailed multivariate analysis of data from the courtrooms surveyed. The analysis in this thesis constitutes the first scientific study of courtrooms as a work setting, and includes physical and environmental variables, as well as factors contributing to courtroom symbolism.

The modeling effort made in this study also begins to address numerous other avenues of academic interest. Its contribution (value addition) to the ongoing IAI-IFC efforts towards developing a standardized, comprehensive building model of as-designed data constitutes one issue of interest. In addition, the model, at least theoretically, begins to offer a medium for greater interaction and dialogue between researchers within and across research communities. Most importantly, however, it offers a new perspective on POEs and the way they need to be conducted to be of added value to the building design community. The concluding chapter includes discussions in these areas (chapter 10).

To summarize, the primary focus of this study is on determining the feasibility of using EXPRESS conceptual modeling language to model POE data, and integrate POE data with as-built descriptions of built settings (courtrooms). To demonstrate the utility of conceptual modeling in providing information support at the design evolution phases,

several additional tasks were warranted/ involved. First, several possible scenarios of information support at design evolution phases were identified. This list of scenarios was inferred from existing models on the design process articulated in EB literature (chapter 2). Additional scenarios, arguably, could be added to the list, although it was assumed that the six scenarios amply demonstrated the information support potential of the modeling effort. Second, in order to provide useful/ meaningful information, the types of data dealt with in conventional POEs were studied (including those related to courtrooms). The study suggested that the data types dealt with in conventional POEs need rethinking, especially from the performance framework – the framework that determined the data content independent of the modeling process. The changes suggested to the POE data content constitute the first step in viewing POEs from within the performance framework, which would arguably be improved/ modified through further research. While these additional works were primarily warranted to demonstrate the potential of the modeling effort, it, nevertheless, resulted in some significant byproducts of this study in the form of new findings and novel arguments. Several chapters in this dissertation, including portions of chapter 4, chapter 5, chapter 6, chapter 8 and chapter 9 should be viewed in line with the study description made here.

1.1 Chapter summaries

- Chapter 2 begins by elaborating the developments in the fields of EB and building engineering that inspired this study, and provides an historical overview of

discussions in EB literature related to expanding the utility of POE data.

Impediments resulting from traditional POE practices are discussed.

- Chapter 3 begins by articulating the main question of this study, proceeds to explain the significance of this study, and outlines the research design.
- Chapter 4 provides an in-depth description of the American judicial system and courtroom functions.
- Chapter 5 provides a comprehensive overview of factors in the environmental and physical domains that have been highlighted in literature as important variables influencing task performance. It also defines the scope of the study.
- Chapter 6 outlines the data types included in the study and the instruments used for data collection. The chapter also includes a description of the sample and the method adopted for selection of sample.
- Chapter 7 explains the EXPRESS-G building model developed in this study and the design of the relational database for instantiation of POE data.
- Chapter 8 outlines six types of query generated outcomes from the data model and the database, with worked out examples for illustration.
- Chapter 9 includes two types of outcomes from statistical analyses of data. The first outcome includes multivariate regression models. The second outcome pertains to development of courtroom KPIs (key performance indicators) from POE data.
- Chapter 10 outlines several implications of this study and future directions of research.

Chapter 2

Data from Buildings-In-Use

“In her study of playgrounds, Lady Allen of Hurtwood (1969) asked: “Why [are] so many expensive mistakes...made over and over again? One reason may be that there is no central body whose job it is to collect experience and research throughout the world, digest it, and make it readily available to architects and planners” (quoted in Sommer, 1972, p.102). These and other authors have proposed a central repository for building designs, complemented with evaluations of the finished products. However, once these evaluation studies are collected, exactly how would they be combined or analyzed to determine what works and what does not?” (Gifford, Hine, & Veitch, 1997)

The field of Environment Behavior Studies originated during the 1960s with the intention to study interactions between the physical environment and users, and to provide support to the design professions in creating settings that supported individual, organizational and cultural needs and behaviors. Post-occupancy evaluation (POE) developed as a methodology to investigate buildings-in-use, and identify links between the built environment and user needs. While POEs have proved valuable for decision making in facility management and organizational learning, they have been less effective in supporting design. This chapter argues that while a major shortcoming lies in the characteristics of conventional POE data and data structure, issues also typically overlooked include the type of end-users and the type of decisions supported by the data.

This chapter includes:

- 2.1 EB studies and POEs
- 2.2 POE data and design decision support
- 2.3 Issues in designing information support

- 2.3.1 Data content
 - 2.3.1.1 Characteristics of data
 - 2.3.1.2 Characteristics of data structure and feedback
 - 2.3.1.3 Characteristics of POE
- 2.3.2 End-user and decision type
- 2.4 Design decision support
- 2.5 Summary

2.1 EB studies and POEs

Can data generated in POEs be structured to provide support information for design and design review, as well as for discovery processes in academic inquiry? Considering the multi-disciplinary nature of the study, it is prudent to explain, at the outset, some of the important terms used in this and subsequent chapters. Table 2.1 below lists the key terms.

Table 2.1: Key terms.

| Terms | Explanations |
|------------------------|---|
| EB | Acronym for Environment-Behavior Studies. A multi-disciplinary branch of study that focuses on the interaction between the environment (physical, social, organizational, etc.) and the users. |
| POE | Acronym for Post-Occupancy Evaluation. FPE (acronym for Facility Performance Evaluation) is increasingly being used in place of POE. A type of evaluation methodology that captures the degree to which a built setting satisfies organizational goals, design objectives, and user requirements. |
| Design decision making | Steps in a design process that involves defining solution spaces and evaluating decisions based on defined (mutually agreed upon) criteria. |
| Design review | A stage in the building procurement process where a committee of stakeholders assesses a range of alternative design solutions (or a single design) to identify the one that best serves their goals/ requirements. |
| End user | An individual, having a stake in the final design, acting on a set of data intending to derive information to support the task at hand. |

Table 2.1(continued)

| Terms | Explanations |
|----------------------|---|
| Data characteristics | The aspect of the environment (physical, social, organizational, etc.) or user that is described by the data. The mode of description – textual, numeric, etc. |
| Hard data | Description or performance data that does not reflect the influence of human psychological mechanisms on measurement outcomes. |
| Soft data | Data that reflect the influence of human psychological mechanisms on measurement outcomes. |
| As-built data | Descriptions of a setting's physical and environmental characteristics (including technical performance data) as measured on site. |
| As-designed data | Descriptions of a setting's physical and environmental characteristics (including technical performance data) as intended (projected) during design. |
| Data storage | A medium that simply stores data, without explicitly articulating the relationships between the data. Spreadsheets, statistical software, text software, printed documents are some examples. |
| Data structure | A semantic structure that articulates the relationships between data types, and offers meaningful placeholders for data. |
| Feedback | The output of a data processing step intended to provide information to an end-user. |
| Uses of POE | The use to which the outcomes of POEs are subjected, such as facility management, portfolio management, organizational learning, needs assessment, design decision making, etc. |

Environment and Behavior studies (EB) developed during the early 1960s as a field of scientific inquiry in response to an enhanced awareness about the environment, and a perceived need for decision-making support related to users of built spaces, in the design profession (Saarinen, 1995). A major incentive in creating the field was to enhance the utility of academic research and, especially, to provide design support information to the architectural and planning professions. Over the decades, EB developed as a loosely-defined field that was focused on understanding how the physical environment and human behavior interrelate, and incorporated many sub-fields and foci such as environmental psychology as well as foci on setting types, users or behaviors. Some of EB was applied and was intended to improve decision making at multiple scales.

POE started as a methodology, within the EB umbrella, to provide user input and has expanded to a practice that incorporates user feedback along with technical and financial performance. Starting with one-off studies during the late 1960s (Preiser, 2001), initial efforts were focused on solving problems related to housing needs of disadvantaged people and improving the quality of public housing (Vischer, 2001). The 1970s witnessed major expansions in POE studies. Courthouses, prisons and hospitals were targeted for evaluation (Vischer, 2001). Preiser et al. (1988) report that this period witnessed the first major collaboration between architectural and medical professionals in hospital design. During the same period offices and schools were beginning to be targeted by POE researchers in the Great Britain (Preiser et al., 1988). The period, on the whole, witnessed an adaptation of research methods and tools from diverse fields in POE studies, including survey, interview, observation techniques, cost-based building evaluation model, triangulation methods, systematic observation, behavioral mapping, archival data, and photographic records. POEs, with the new tools, embraced a wide variety of building and occupant types for systematic study. The large body of knowledge, generated in the process, led to the development of a number of design guides and standards (Preiser, 1994). Some researchers began to expand POEs from one-time, single unit evaluation to system-wide evaluations (Preiser, 2001).

The progress during the 1970s helped POE develop into a discipline on its own right during the 1980s, with a established network of researchers, a developing corpus of knowledge, and a bag of accepted research tools and methods (Preiser et al., 1988). The

1980s also attracted the attention of the private sector, and occupant satisfaction surveys were conducted in numerous offices, schools and hospitals. The energy crisis of the 1970s, and the subsequent thrust in building component manufacturers towards developing energy efficient systems, led to the expansion of POEs into domains of energy use and occupant comfort (Vischer, 2001).

The developing corpus of knowledge, methods, and expertise resulted in some other outcomes too. During the 1990's POE tools and data were considered appropriate to develop accountability measures. Joiner (1996) discusses the growth of POE in New Zealand, where government architects, until then, used accounting and engineering measures (principally time and cost) to demonstrate performance of buildings. POEs introduced new measures of performance by demanding ways of demonstrating that the designed settings work well for the users and building managers. Since then, POE has emerged in New Zealand as a process offering social negotiation between stakeholders of a building project. Other contemporary developments in POE includes the process-oriented approach propounded by Preiser (1996), that also examines influential economic, political, social and regulatory factors that impact the outcome of a building procurement cycle. Preiser (2001) attempted to rename POE as BPE (Building Performance Evaluation), and UDE (Universal Design Evaluation). His attempts has been towards effectuating a more holistic approach to building evaluation that also takes into account important factors influencing the process leading to the building product.

Along with the evolving practice of POE, the declared purpose of POEs has changed too. While initial POEs often focused on single buildings (which continues to be a vital objective area) newer requirements for POEs have surfaced. The US General Services Administration has adopted evaluation as a key component of their innovative WorkPlace20.20 program, where technical, organizational and user-oriented evaluation is conducted both before and after office renovations (Kampschroer & Heerwagen, 2004). More recently, the possibility of systematic organizational learning through POEs have been explored (Zimring, 2001), and in the future such a purpose could also be assigned to POE studies (or any other appropriate name that might be assigned to this class of research; FPE, acronym for Facility Performance Evaluation, is already in vogue in large organizational owners of real estate). Appendix II, section 2.2 includes a detailed discussion on POEs.

2.2 POE data and design decision support

Despite their considerable growth over the past decades, POEs represent an important missed opportunity. While POEs are often used to inform design guides (Kernohan, Gray, Daish, & Joiner, 1992), and to support facility management (Zimring, Wineman, & Carpman, 1988), they are seldom used to support design decision-making (Kernohan et al., 1992; Zimring, 2001), one of the principal original objectives of EB research. POEs, nevertheless, could provide significant aid to improving building performance by design. For instance, evaluation studies include important lessons-learned data that could provide decision-making support in building design. Further, the user data in POEs are collected

in non-contrived settings, enhancing their validity as compared to laboratory studies. EB researchers have, time and again, underscored the potential use of POE data in design decision support. Robert Bechtel (reported by Zimring, 2001) estimated that more than 50,000 POEs have been completed, but little in terms of guidance document or other decision support mechanisms has materialized. Zimring (2001), among others, believes that POEs have a rich potential of providing support in programming, design decision-making and design review. He, however, points out several problem areas - some organizational/cultural, some methodological and some technical - that act as impediments to any enhanced application of POE results. His comments were made in the context of organizational learning, many of which are also true in case of design decision-making, namely:

- Historically, POEs have focused on single cases, with little emphasis on generalization of findings: historically POE studies have emphasized on the uniqueness of a particular setting as opposed to commonalities across settings. Further, the main attempt has been on assessing a single building's performance with the view to identifying immediate and potential problems associated with a particular facility. Developing immediate, short-term and long-term corrective measures for better performance and/or adhering to codes has been the focus of the exercise. The question of using any knowledge gained in other projects in a structured (generalizable) way has not received necessary attention. Plausible reasons could include the client's interest in the immediate issue at hand. Zimring also points out that typical POEs have been looked at from within the narrow

perspective of facility maintenance/management, thus precluding any attempt at applications in other areas, such as design decision support.

- Study outputs (in form of reports) are not amenable to large-scale dissemination of findings.
- There have often been limited attempts at distribution of reports internally, or to outside consultants and the public: client organizations may not possess the capability to capture knowledge generated from building evaluations and disseminate the knowledge in a formal manner. It is quite possible that, as Zimring suggests, in many cases distribution of POE findings is intentionally avoided, lest they may highlight failure within the organization.
- There is no mechanism to ensure that information provided to support decision-making is kept current: the necessity to ensure that data available for decision support is current needs no elaboration. Although the physical world may be assumed to remain unchanged over prolonged periods of time, cultural aspects of behavior settings do change in shorter periods. The desire on the part of organizations, and modalities to update data made available to decision makers constitute a major organizational hurdle.
- Forms of feedback (from study results) are not appropriate to support the kinds of decision made by end users (designers, organizations, etc.): data and analysis of data from POE studies are inappropriate in form and/ or content to address the kind of information support sought by decision-makers. Data/ information that could help support decision-making, and that are intuitively appealing to the end users are lacking.

- Lack of incentives for using POE data and contributing to lessons-learned knowledge base: there appears to be an absence of any system that rewards people, materially or otherwise, who would engage in processes that generate and feed information to the decision-making process.
- Disincentive for participation in lessons learned program/ innovations: innovations in design and management may result in negative assessment in the instances of failure. This has kept many people away from participating in information feed forward/ back programs that could generate new and more relevant knowledge.
- Lack of high-level support within organizations for lessons learned programs.
- Lack of awareness among project stakeholders about the existence of POEs: even when stakeholders are aware, access to past POEs has been difficult. Zimring's study of 18 organizations points to the fact that stakeholders of new projects are very often not aware of the existence of any prior POE studies. Access to past POEs is a major problem since POEs are not produced, stored, and indexed/ cataloged in a manner that is amenable to easy retrieval when needed. Searching for relevant POE-based data, without proper storage and retrieval system constitutes a major hindrance.
- Absence of a body of knowledge that is integrated and coherent: An integrated body of data from building evaluations has not been made available to building procurement teams.

It might not be erroneous to state that the role of POE studies at this juncture, in informing and educating subsequent building procurement processes as well as in supporting academic inquiries, have been at best informal and restricted in influence. More specifically, POEs have not been broadly successful in informing designers of buildings, who constituted the primary target population at the time EB study was developed as a discipline (Zimring, Wineman, & Carpman, 1988). It should be noted, however, that the POEs covered in this discussion are mostly English language-based, and it is possible that POEs conducted in countries speaking other languages might be witnessing greater use in informing design. In the building procurement process, a major source of learning, thus, remains untapped. Traditional academic inquiries about building performance, too, which are mostly dependent on specially designed investigations that are expensive, time-consuming, and constantly endeavoring on issues of validity in contrived research settings, suffer from lack of access to context-rich data.

The potential of EB research studies in general, and POE studies in particular, in informing the building design and procurement processes is reflected in the discussions and debates in EB as well as engineering literature. The discussions mostly pertain to:

- Lack of information transfer between EB research and design practice.
- Limited utilization of POE data.
- Greater necessity of data from buildings-in-use.
- Need for feed-forward of information and the potential of integrated databases as a means for information transfer.

Many thinkers in the EB domain have, for long, pointed out the lack of availability of pertinent information related to user-environment interaction to design team members of new projects, as a way to inform the decision making process in building design and procurement (Sommer, 1974; Zeisel, 1984). They cite the designer-user gap as the reason warranting enhanced interfacing between research findings and design decisions. These views are expressed within a larger concern about limited utility of EB research findings (Zeisel, 1984; Zimring & Reizenstein, 1980). Some have specifically lamented the limited usefulness of data generated through post-occupancy evaluations (Joiner, 1996; Kantrowitz & Nordhaus, 1980; Kernohan, Gray, Daish, & Joiner, 1992; Keys & Wener, 1980; Vischer, 2001), arguing that evaluation data are either not used in design practice or have been instrumental mainly in the narrow sphere of creating guidance documents. They have underscored the inaccessibility of POE studies to potential users outside the client unit/ organization, as well as the deficiency in POE formats that would not support easy transferability to other use scenarios. As pointed out earlier, POEs are the most frequently used means of building evaluation, which may partly explain the focus on this form of evaluation by many. This point is further elaborated in Appendix II, section 2.1.1.

These reflections on data from buildings-in-use, however, are not limited to the EB domain. People engaged in research and practice in the fields of building engineering and building physics have, of late, been expressing the need for data from buildings-in-use (Becker, 1996; Gross, 1996). The gradual shifting of building procurement and evaluation practices from prescriptive to performance based ones has encouraged a

rethinking on the definition of the term ‘performance’, driving engineering designers to seek new information related to users and activities hitherto unsolicited. The importance of learning across design phases, and the deficiency of it, is highlighted by many (Masat, 1996; Wiezel, 1996). Learning from buildings-in-use, and feeding such information to subsequent design cycles is underscored as crucial to improving building performance. In essence, the building engineering researchers are in search of data on the way people actually use built environments that are designed for optimal performance. This paragraph is further elaborated in Appendix II, section 2.1.2.

Over the past four decades of POE research (the predominant focus on supporting facility management decisions notwithstanding) the desire to support design decision-making has not receded. That is partly reflected in the more recent emergence of non-traditional research practices. Some evaluators have attempted to resolve the problem of data utilization by proposing participatory practices. Researchers have adopted methods named in the field as ‘action research’ and ‘reflective practice’, to interface research knowledge and design decision-making. ‘Placemaking’ (Schneekloth & Shibley, 1995) and ‘Process Architecture’ (Horgen, Joroff, Porter, & Schon, 1999) are revolutionary practice methods that have surfaced in the past decades, where researchers have been taking on more active role in knowledge generation and transfer through proactive involvement in professional projects. The researchers involved in such practices underscore the way it empowers users, as well as the benefits that accrue from tapping into the rich everyday knowledge held by users of built spaces. Methodologically action research and reflective practice are different from traditional POE studies. They use

organizational learning tools as opposed to observation techniques or questionnaires.

While it may be argued that Placemaking and Process Architecture essentially constitute a new practice paradigm, they also represent the interfacing of research knowledge and design practice. Preiser (1996) has developed yet another modality for knowledge transfer. Typically, he teams up with the designers and provides evaluative support at various design phases based on contextual knowledge personally gathered through years of consulting and research.

In more traditional research, proposals for integrated databases for storage and retrieval of building evaluation data (Masat, 1996; Zeisel, 1984) have been offered as alternative ways of feeding information to pertinent decision-making phases (see Appendix II, section 2.1.3 for more details). However, as Zimring (2001) points out, creating integrated knowledge bases is easy in theory, but has proved difficult in practice.

Building procurement teams represent a varied professional culture, with quite different requirements for decision support. Zimring notes that researchers have not been able to handle successfully the translation between data types and information requirements.

To summarize, it could be stated that:

- Feeding data to design decision-making phases has been limited by modalities of data collection, representation, and practice.
- POEs are a rich source of data from buildings-in-use, are the most frequently used building evaluation study, and offer a potential for informing design decision-making.

- A method to enable information support in building design, and access to POE data for academic inquiry is not forthcoming.

This thesis is based on the argument that a methodology could be developed, using recent developments in conceptual modeling, which could begin to address some of the impediments highlighted by Zimring (2001). Zimring's list, as noted earlier, could be categorized into organizational/cultural, methodological, and technical impediments, and it is asserted that the methodological and technical impediments could be addressed by the method proposed in this study. In essence, this study involves the structuring of POE data and process in order to inform building design and design review, as well as enable access to data to support academic inquiry in studies on human-environment interactions. Three issues, lacking in traditional POEs, warrant attention in order to achieve the above objective: data content, decision type, and end-user. Those issues are covered next.

2.3 Issues in designing information support

Shortcomings in traditional POEs arise from three areas of importance:

- Data Content
 - Characteristics of data
 - Characteristics of data structure and feedback
 - Characteristics of POE
- Decision type intended to be supported by the data
- Type of end-user of the data

The three issues are not mutually exclusive. All three issues influence the information-support potential of POE studies during the design phases, and in turn constitute the major areas of implication of this study.

2.3.1 Data content

2.3.1.1 Characteristics of data

For the purposes of this dissertation, characteristics of data include: 1) the attributes of a setting on which data is collected; 2) the types of evaluation data sought during a study; and 3) the ways measurements are conducted.

Data collected during POEs could include data on physical elements (envelop, finishes, furniture, fixtures, etc.), technical performance data, user characteristics, etc. For this discussion, attributes of a setting include all such data on the as-built environment and data on the users of settings.

A setting could be evaluated in many ways. Evaluation of the performance of building elements (envelop, windows, HVAC systems, etc.) constitutes one type of evaluation data. Other evaluation types include those involving user surveys, observations, touring interviews, etc.

A final issue related to data characteristics pertains to measurements. The previous two issues relate to ‘what’ is being measured. This issue relates to ‘how’ the measurements are conducted.

Characteristics of data in traditional POE studies constitute a vital shortcoming from the viewpoint of design decision support. Typical POE studies have predominantly focused on measuring satisfaction scores of users on standardized, ordinal scale measures. The exceptions are POEs using organizational learning tools (such as touring interviews). The outcomes of such data provide valuable input to decision making in facility and organizational management. However, satisfaction is a complex construct, and satisfaction scores are not well suited to provide design decision support or the precision required in traditional academic inquiry. For instance, a designer (end-user) could be seeking information on the size of a work surface (length, depth) for optimizing work performance. Satisfaction with one’s work surface could, however, include numerous other issues, such as work surface material, how fashionable the design is, or ones degree of involvement in the design of the product (POEs using organizational learning techniques gather a richer set of data from user evaluation. Such types of POEs are not within the scope of this thesis; but they constitute a good domain for further studies in POE data modeling).

A distinction is warranted here between satisfaction questions from the viewpoint of question typology, and satisfaction as the thing/ construct being measured. In essence, the examples cited here are all satisfaction questions (from the viewpoint of question

typology). The difference lies in the thing that is being measured. User satisfaction continues to be measured in contemporary POEs, such as satisfaction with the functionality of courtrooms (among others) in the CBE/GSA customer satisfaction survey (CBE, 2001), and satisfaction with the building design in PROBE (Cohen & Gilbert, 1999). For courthouse facility managers, monitoring satisfaction scores could provide valuable information about spaces in the courthouse needing immediate attention. For designers of other courthouses, however, satisfaction scores on courtrooms provide little in design support input.

Yet another issue on data characteristics is one of incomplete data sets. Data on the environment and user behavior constitute the founding blocks of typical EB studies. POEs focusing on satisfaction, efficiency, and performance across settings often consider numerous aspects of the socio-cultural domain, but (generally) provide an incomplete investigation/ documentation of the as-built variables influencing occupant behavior. For instance, satisfaction with the lighting environment may be measured, but without the corresponding data on the precise task types performed by the user, lighting levels or the types of lighting provided. In studies that include environmental descriptions, the illuminance levels are typically measured, although most engineering literature hypothesize that luminance (brightness) bears greater influence on performance. In some instances the physical variables are completely ignored. For instance, data could include user's reaction to noise in work settings without the corresponding acoustical measures. For instance, the CBE survey (mentioned above) includes questions on satisfaction with the amount of light and visual comfort in one's workplace. However, this evaluation data

is not supplemented by measurements of actual lighting conditions – illuminance, luminance, glare, etc. which would complete the environment-behavior equation. In other words, POEs have been lacking appropriate levels of description of the as-built environment. Presumably, a designer could make use of evaluation data only when as-built building descriptions are available. In order to conduct prediction and testing, data on all hypothesized physical/ environmental variables need to be made available. Existing studies in EB and building engineering offer a good source of information on hypothesized influential variables. Such studies, however, have not uniformly driven the substance of POE studies.

2.3.1.2 Characteristics of data structure and feedback

While inappropriate data and incomplete data sets constitute one aspect of the problem, a different kind of hurdle relates to the way POE data are stored and managed. To articulate this point better, imagine a situation where a designer is required to use POEs to inform his decisions in a (hypothetical) project. The outcomes of most POEs are in the form of printed reports. The first task, thus, is to search and compile all POEs relevant to the design task. Once the POE documents are compiled, the designer's task is to search and extract the relevant data from the documents. Assume that the designer is looking for evaluation data on the depth of judge's bench in courtrooms. The first task is to search and locate in each POE document the exact location where such data are presented (see figure 2.2, for instance). The subsequent task will be to extract each as-built and evaluation information to a third medium in order to interrogate/ process the data and extract useful information. The process needs to be repeated for each and every area of

information support. The amount of time and effort needed to extract relevant data needs no elaboration.

The situation could be viewed from the viewpoint of data storage and management. It appears that conventional POEs focus mostly on data storage, and less on data management. Further, there appears to be a conflation between storage and presentation, where the printed reports serve both purposes. To rephrase the above discussions:

- Conventional POEs focused more on data storage and less on data management. Such storage included printed documents as well as electronic storage systems including word applications, spreadsheets, and statistical software. Most POEs used one or more of the storage systems, although the primary focus has been on the final output in the form of printed booklets.
- The printed reports have been the main focus of storage and management of POE data.
- Data (text as well as numeric) from which the final outputs (printed documents) are produced have been less accessible as compared to the latter. Textual data could include users' comments, experts' observation, etc. Numeric data could include technical performance measurements, users' evaluation data, etc.
- Issues related to management of POE data for various end uses have not been discussed in literature.

Data structure, in this discussion, pertains to the articulation of the way different elements and their attributes are related, from a viewpoint of data management. Do conventional

POEs attempt at structuring the data that are collected? In some ways they do. For instance, textual data collected during POEs are, in many cases, subjected to content analysis with the objective to identify clearly defined domains and classifications of issues. However, such tasks have generally been performed outside the purview of managing data for targeted end-uses. As a starting point, this thesis is focused more on numeric data collected during POEs. Generally, numerical POE data are placed in tables in a spreadsheet or statistical software database. Typically the columns include the fields/variables, and each row holds data on one case/record. The data is then used for some form of statistical or mathematical analyses that provide information of interest to the researcher. The information generated is then disseminated through some form of publication. As suggested above, the scenario presented here is limited to data storage, so far as handling POE data is concerned.

From the viewpoint of integrating POE data from multiple studies, some examples of possible pitfalls would serve to highlight potential impediments. For representing data from a single study, or from multiple studies with identical list of variables and simple data structures (such as one-to-one relationships between variables), the traditional model of practice would probably not pose any major problem. However, variables in POE studies do change across studies. Moreover, numerous real world relationships between data types are more complex than the one-to-one relationship, for which spreadsheets and similar data storage systems are more appropriate. One-to-many and many-to-many relationships are commonly encountered in research. At the most fundamental level, consider the domain of EB studies. Typically EB studies focus on setting types, issues, or

user types. Thus, integration efforts of POEs across studies would encounter many-to-many relationships between the three areas of focus – a setting type could have multiple issues and user types, an issue could be studied across setting types and user types etc. More complex relationships between data types are also frequently encountered.

Structuring data using traditional storage-centered practices to accommodate changing clusters of variables, and complex relationships (if not impossible) could result in extremely complicated representations that would be difficult to manage, comprehend and query. For example, consider a hypothetical evaluation of courthouses. Judicial districts, courthouses, courtrooms and users, or even lighting fixtures and courtrooms, have complicated relationships. A particular judicial district could have many courthouse types while a courthouse type could be found in many judicial districts. A particular courtroom user (say a court reporter) could be using more than one courtroom whereas more than one reporter could be using a particular courtroom. A particular type of lighting fixture could be found in multiple courtrooms whereas a single courtroom could have multiple lighting fixture types. Representation of such relationships on single tabular data storage structures could render the representation extremely complicated and unmanageable, owing to multiple replications of records.

Yet another example pertains to classifiers of data. A major objective of most data structures is easy and meaningful retrieval of pertinent data. Towards that objective data are classified into meaningful chunks, and numerous identifiers are assigned as attributes. For instance courtroom type (district, magistrate, bankruptcy, etc.) could be used as

identifiers so that data retrieval could be more focused, as opposed to extracting large volumes of data that are not required for the particular end-user task being performed. Similarly, environmental variables could be classified into such domains as visual, auditory or thermal. Incorporating such classifiers/ identifiers in traditional representations could result in meaningless data tables, such as courtrooms being identified with auditory data types, or illuminance being identified with courtroom type, since they end up sharing the same row associated with a particular record. Such issues may not have surfaced in POE practice since attempts at aggregated representation of POE data (or the success of such attempts) have not been widely reported in literature.

For large data sets, holistic representations of all data types and their relationships constitute one key to meaningful extraction of information. Potential users of the secondary data would get the best of the data only if the relationship descriptions are available and are explicit. In traditional data storage systems, representing complex relationships could be complicated and difficult. Complex, abstract concepts and relationships cannot be represented in the system, although separate articulation of the concepts can be (and are) accomplished. For instance, in a study on openness of contemporary federal courthouses the investigator (Pati & Zimring, 2003) found that openness is frequently conceived of in six different ways: accessibility, transparency, exposure, organizational clarity, illumination and inclusiveness. Further, some of the areas of conceptions had multiple interpretations. Similarly, interpretations were associated with multiple ways designers have translated openness into actual design decisions. A POE of courthouses could collect data on each of the attributes related to the

translation areas. Traditional data storage could hold measured data on attributes of the building as well as users' feedback from a POE survey. However, the exact way the building attributes relate to the interpretations and conceptions of openness would not be articulated. For small datasets it may or may not pose a problem. However for large data sets from multiple studies such issues could reduce the comprehensibility of data. Figure 2.1 graphically illustrates the issues discussed above.

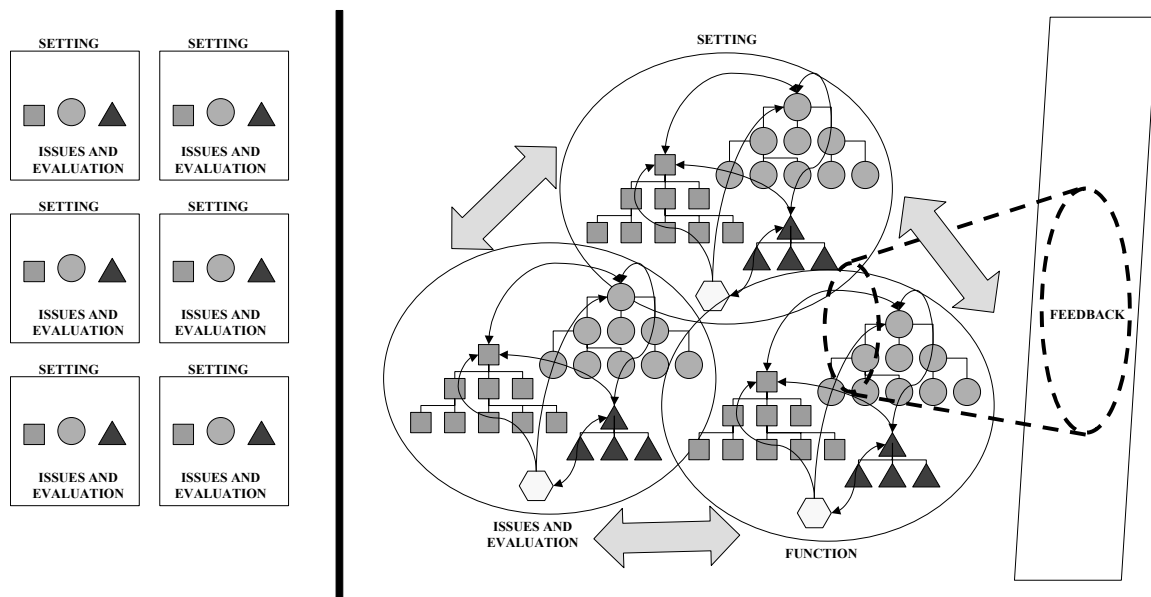


Figure 2.1: Traditionally POEs resulted in a conflation of storage and feedback (left) plagued with inappropriate data and incomplete data sets. For design information support complete data sets and articulation of data structure is warranted (right).

Finally, feedback characteristics are also important. Problems associated with storage and presentation through printed documents is already addressed above. Figure 2.2 shows a page from a typical POE study. While such a type of storage and presentation format may have worked well for corrective measures in newly built facilities, facility management

or other organizational goals, they may not prove amenable to easy data integration across POEs, or querying of data for providing information support at the design and design review phases. Several other issues related to feedback characteristics have been dealt with in literature. Such issues, including level and frequency of feedback, and feedback format (qualitative versus quantitative) are not within the scope of this study.

| United States Courts Courtroom Post Occupancy Evaluation Sheet | | | | | | District Court Magis | | |
|--|-------------------|-------------|----------------|--|------|--|------------|--|
| Date of Occupancy: October 1994 Date of P.O.E.: May 1995 | | | | | | Abbreviations: U.S.C.D.G.: Specification of U.S. Loc.: Location of area of c Int.: Interview response i Quest.: Questionnaire respo P.O.E.: Post-Occupancy Eve | | |
| DESIGN CATEGORY | | | | User Comment | Loc. | Source | POE | |
| U.S.C.D.G. Actual | | | | | Int. | Quest. | | |
| A. SPACE, FURNITURE, AND FINISHES | | | | | | | | |
| I. | Size (NSF) | 1500 | 1,460 | Size restricts spectator capacity. | | | Slightly # | |
| II. Built-In Furniture | | | | | | | | |
| a. Bench | | | | | | | | |
| | Length | 12'-0" min. | 11'-2" | | | | Good sig | |
| | Depth | 30" | 24" | Phone and data outlets are present, but no equipment installed at bench. | A | ✓ | Bench in | |
| | Storage | | | | | | A/V stora | |
| | Bookshelves | 6 LF | 5 LF | No place for a keyboard. | A | ✓ | Bench la | |
| | Drawers | 1 | 2 | Equipment will not fit in equipment cabinet. | A | ✓ | Restrict | |
| | Height | 21" A.F.F. | 19 1/2" A.F.F. | No use was made of the space under the bench for storage, etc. | A | ✓ | | |
| | | | | Use of bench was poorly planned and we had no input. | A | ✓ | | |
| b. Deputy Clerk | | | | | | | | |
| | No. of work areas | 2 | 1 | Work station too narrow, particularly with the addition of a computer. | B | ✓ | Deputy c | |
| | File storage | 2-20" | 1 | Distance between judge's bench and deputy clerk's | B | ✓ | Work sp | |
| | Shelving | 1 | None. | and law clerk's stations is a little far. | | | Work top | |
| | Drawers | 1 | 1 | More work area needed, especially for trials/exhibits. | B | ✓ | Inaccess | |
| | Height | 7" A.F.F. | 6 1/2" A.F.F. | Could use more storage. | B | ✓ | Restrict | |
| | | | | Must turn around to see Judge. | B | ✓ | | |
| | | | | Probably not enough space for computer, printer etc. | B | ✓ | | |
| c. Court Reporter | | | | | | | | |
| | Moveable | | | | B | | Deputy c | |

Figure 2.2: Partial image showing typical format for feedback in numerous POE studies (source: AOUSC, undated).

2.3.1.3 Characteristics of POE

The problem with data characteristics discussed above could be partially attributed to the framework within which a large number of POEs have been conducted. Taking two decades of social science research into consideration, McGrath (1982) asserted that social

science studies typically involve three types of goals: 1) contextual realism, 2) precision, and 3) generality. Zimring and his colleagues later suggested that this framework also applies to POE (Zimring et al., 1988). Most POE studies fall within the first category. Studies targeting contextual realism attempt to capture the uniqueness of a particular setting. Outcomes of such studies are directly applicable to the study setting. Part of the reason for such a focus could be ascribed to the developmental history of POEs where client organizations used (and funded) POE studies as tools for organizational decision-making (Zimring et al., 1988). More recent developments in EB research, such as Placemaking and Process Architecture, also fall within this category of research goals. A separate category of study, with the primary goal to increase precision, attempts to reduce the number of variables through experimental control mechanisms. Most engineering research as well as many EB research fall in this second category. The main thrust of such studies is to obtain a precise understanding of the relationship between a limited numbers of variables. The third category of study goals relates to generality of study findings, and attempt to render the findings as widely applicable as possible. The outcomes of the first two categories of studies, in essence, cannot be generalized. That partly explains the lack of utilization of POE data in design decision support, barring cases where the POEs and design decisions relate to the same building project.

As Zimring et al. (1988) point out, studies attempting contextual realism maximize the number of variables in order to get a comprehensive picture of the setting and/or organization under study. In precision studies, the numbers of variables are reduced, but attempt is made to maximize the number of observations within each category of data. In

order to provide design decision support, generality is warranted. Attempting generality (for design decision support) would warrant large number of observations as well as large number of variables. Attempting both, within a single study, could be prohibitive in time and cost. In fact, McGrath referred to it as the “three-horned dilemma” (Zimring et al., 1988), asserting that increasing focus on one necessarily entails a reduced focus on the other two. Integrated data structures serving as repository of POE data originating from multiple studies may provide one way of addressing this issue.

While integrated data structures could help address the issue of generality, the performance based framework initiated in building engineering offers fresh directions in designing POEs. Over a long period of time researchers in design cognition and computing have attempted to understand how designers design. In a vast majority of the cases the researchers have made efforts to understand how designers design so as to develop systems that could assist in the design process, and, in some instances, even fully automate certain design tasks (Eastman, 1999, provides a good review of research endeavors in this domain). According to some, however, most of the works have produced limited success in providing support to the designer (Kalay, 1996). Kalay argues that some of the reasons that the research efforts on providing design support have not been as successful as intended lies in the paradigmatic orientation. He highlights aspects of prior research efforts that, according to him, need rethinking. It relates to the continuing fascination and emphasis by researchers on unearthing causal relationships between form and function. That, according to him, has led to two different paradigms of research: problem solving and puzzle-making. The problem solving angle, involving

deductive reasoning, views the designer as starting with a set of sought functions that ends with an optimal form. On the other hand, puzzle-making, involving inductive reasoning, views the designer as beginning with a set of forms and proceeding through a series of modifications until certain desired functional qualities are achieved.

Kalay rejects both paradigms as unsupported by empirical findings. Instead, he asserts that designing is an evolutionary process involving several intuitive leaps. The extreme difficulty in comprehending and rationalizing this tacit, apparently irrational process leads Kalay to propose an alternative approach that could achieve better success in providing design support. He suggests the performance-based paradigm as a possible solution. In his view a successful way to provide appropriate design support is by focusing on ‘what’ designers do when they design rather than focusing on ‘how’ they do it (design). Describing his focus on ‘what’, he asserts that what designers need is the ability to reason about a particular combination of form, function and context. He provides an alternative articulation of the design process, where an iterative process is used to explore and determine the confluence of form and function within a given context – or the extent to which a particular combination of form and function perform in a given context. He calls the achievement of acceptable performance of form and function, within a particular context, as functional adequacy. From the perspective of this dissertation, Kalay’s approach suggests that POE results can be made more useful to design if the end-user can query the information in a flexible and recursive way, moving from description of context and past cases to more specific testing of design-behavior fit.

Kalay's approach complements two well-known models in EB literature. One is proposed by Zeisel (1984) and the other by Lang (1987). Zeisel's model on design process is founded on a spiral metaphor (Figure 2.3). It articulates five salient features of the implicit design process: 1) imaging, presenting and testing as three primary, repetitive activity of the designer, 2) image information and test information as two information types supporting design process, 3) design process progressing through a series of conceptual shifts, 4) the notion of a domain of acceptable responses defining the solution space, and 5) design progression through a spiral metaphor, that involves a series of repetition of the imaging-presenting-testing cycle. Imaging, in his view, involves a fuzzy vision of the solution space that aids in fine-tuning the problem. Testing, according to him, involves assessing solutions, incrementally, against explicit criteria and objectives defined by the designer as well as the client, which includes a range of performance aspects that define the solution space. He, essentially, describes the design process as a series of steps where explicit testing criteria helps in optimizing search procedures, and the final product as satisficing the range of testing criteria established by the client, designer, and other stakeholders. Lang's (1987) model includes similar characterization of what designers do. He terms those as basic intellectual activities that include, among others, prediction, evaluation, and decision.

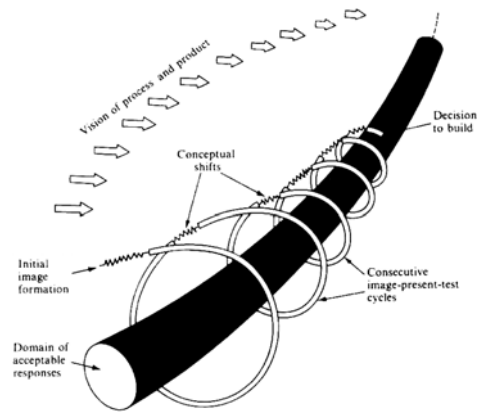


Figure 2.3: Zeisel's model of design development – a spiral process (source: Zeisel, 1984).

Prediction and evaluation (of performance aspects) are common activities portrayed in both models. Further, the notion of evaluation of design decisions as cyclical activities in a design process are underscored in both. Over the past decades, POEs have focused more on supporting facility management and organizational decision-making, and less on what designers need to test their decisions. The performance framework offers a novel perspective to revisit POE design.

2.3.2 End-user and decision type

Yet another impediment in traditional POEs has been the predominant focus on stakeholders in client organizations and on facility management decisions, rather than designers. As (Zimring et al., 1988) pointed out, the major influence of POEs has been on facility and portfolio management, and not on the design profession. Part of the reason could be that client organizations have traditionally sponsored and supported most POE

studies. As Zimring (2001) suggests in his paper, an impediment to any enhanced utility of POE data is the disparity of information types sought by various teams in the building procurement process. For instance, he cites the engineers with technical problem-solving approach as distinct from the architects who are more focused on formal solutions. In contrast, clients are more interested in matters pertaining to usability of buildings and experience of users. From such a viewpoint, traditional POEs are ill suited to support design decision-making. Feedback (information) generation from data, thus, need to address specific informational need of the end users based on the tasks at hand.

2.4 Design decision support

One fundamental issue stands out from the above discussions. In order to inform design and design review, POE data and practice needs to be revisited. Further, modeling POE data and findings should be viewed concurrently with the kind of information that needs to be extracted from the data structure depending on the end-user decision type that is intended to be supported. One, thus, needs to focus on three aspects: the kind of data being modeled, the end user of the information, and the type of decision that needs to be supported by the output. In design decision-making several end-uses are of particular interest, particularly to support imaging and testing. The end-uses identified and discussed here are not exhaustive, and arguably more types of information support scenarios could be added to the list. The scenarios discussed below (and used in chapter 8 for demonstration of outcomes) are used in this study to demonstrate the potential of the modeling process, which is the principal focus of this dissertation.

A common step in any early programming/design involves precedence analysis. The objective is to obtain an overview of the kinds of decisions taken in the past related to a particular building type. Precedence analysis helps define an initial solution space in design decision-making. Another step, consciously or unconsciously taken by designers, is to identify best and worst practices. Both of these activities are parallel to Zeisel's (1984) notion of imaging during design. They result in a fuzzy solution space bolstered by knowledge on design precedence as well as on what works well and what needs work. Currently, no formal method is available for these two important activities. Designers and programmers, mostly, obtain information from architectural journals and through site visits on precedence and best practices. In many situations projects for case studies are identified through personal networks. Such methods, while informative, are restrictive in the width and range of information made available to decision makers. Testing of design solutions and/or alternatives, also a phase described in Zeisel's (1984) and Lang's (1987) model, are even less formally conducted in design practice. The principal reasons include non-availability of study findings, and appropriate representation of feedbacks to enable testing. As a result, as Wiezel (1996) opined, current testing depends solely on the subjective knowledge base of the designer, obtained through incremental learning and experience. Such knowledge bases are unrepresentative, unscientific, and could lead to erroneous conclusions. Testing could take many forms. POE data could help assess design decisions based on user evaluations from similar settings. Similarly, POE data could assist in predicting the performance (outcome) of a design decision, based on accumulated data across POE studies. Finally, designers and academics may also desire to extract raw data from a repository for subsequent analysis in an analytical tool of their

choice. Currently, the end-users do not have easy access to data from POE studies.

Obtaining data from past studies could prove prohibitive in time and effort. For POEs to support design decision-making, the design of integrated data structures need to keep, among others, the above end-user requirements in perspective. This, in turn, brings back the main question of the study: can POE data and as-built building data be integrated in a semantic structure to provide design decision support? This question is addressed in the next chapter.

2.5 Summary

The chapter highlights the numerous discussions in EB literature that focus on the desire to create a mechanism to feed research data and outcomes to designers. Many observers have lamented the limited impact of E&B and POE on design. This dissertation argues that issues related to data content, data structure, end-users, and decision types in traditional POEs might have been a major impediment in interfacing research data with design practice. By rethinking data structures and data content we can make POE much more valuable.

Chapter 3

Research Design

Chapter 2 highlights the fact that data from buildings-in-use have been regarded as bearing potential in achieving one of the main objectives of EB research – that of providing decision making support in building design. Beside several cultural/organizational impediments, there are many methodological and technical impediments that appear to create hurdles in achieving those objectives. A method for structuring POE data in a way that would provide meaningful information, particularly in the context of creating integrated databases, is lacking. The research question, significance and method outlined below originate from the expressed need for value addition to POE data. The chapter includes:

3.1 Research question

3.2 Objectives

3.2.1 Primary objectives

3.2.2 Possible by-products of the study

3.3 Research significance

3.4 Research method

3.1 Research question

The main question that arises from the previous discussions is:

Can data generated in Post Occupancy Evaluation (POE), in the field of environment and behavior (EB), be appropriately structured to provide useful information to stakeholders in the building design and review phases, as well as for discovery processes in academic inquiry?

The study draws on the apparent lack of modality for structured feeding of POE data into the design and design review processes. The thesis asserts that through a restructuring of the POE protocol and integration of POE data with as-built data in a semantic model using product modeling techniques, data on users and their behavior could begin to provide design (imaging) and evaluation (testing) support information in building design. One of the key strategies here is to integrate (hard) building data and (soft) POE data in a single integrated data structure. For the purpose of this thesis hard data would mean description or performance data that does not reflect the influence of human psychological mechanisms on measurement outcomes. Data that reflect the influence of human psychological mechanisms on measurement outcomes are referred to as soft data. One of the ways of assessing a model is to take into account the objectives behind creating the model.

3.2 Objectives

There are several objectives behind the attempt to model POE data in a system-independent, integrated data model. There are primary objectives and some possible by-products. The primary objectives are the ones that constitute the main focus of this study.

The possible by-products pertain to areas that demonstrate potential but are not within the scope of this study. Those areas are discussed in the concluding chapter.

3.2.1 Primary objectives

The primary objectives include:

- To create a data structure that would enable actions on the stored data to support design - decision making in the following ways:
 - Precedence analysis (akin to Zeisel's, 1984, notion of imaging): to enable users to survey the system to arrive at a general idea of the range of values associated with various parameters in actual buildings from the sample of the population available in the database. As the database grows (with data from more studies uploaded into the database) the system would provide richer information.
 - Identify best and worst practices (akin to Zeisel's, 1984, notion of imaging): a function that links evaluation data to actual values of various design decisions. The function is intended to identify cases that reside at the bottom or the top of the evaluation scales for a particular type of task.
 - Assess a design decision based on available data in the system (akin to Zeisel's, 1984, notion of testing): to enable an end user to receive feedback on a certain design decision from evaluation data on similar design decisions in the past.

- Predict performance of design decisions (akin to Zeisel's, 1984, notion of testing): to enable an end user to predict the performance of a range of design decisions based on values specified for each of the areas of decision during a design process.
 - Query and extract raw data for subsequent analysis: to enable end-users to access and extract a subset of the raw data based on their objectives. It is envisaged that users would transfer the data to other applications for further analysis.
- To create a data structure that would enable actions on the stored data that would support academic inquiry in the following ways:
 - Query and extract raw data for subsequent analysis: to enable end-users to access and extract a subset of the raw data based on their objectives. It is envisaged that users would transfer the data to other applications for further analysis. Outcome of such types of application includes the following areas that have been the focus of academic inquiry for a large section of the research community:
 - Identify significant and insignificant variables:
 - Assess relative importance of significant variables.
 - Develop key indicators of performance.
- To create a data structure that would enable addition of data from multiple studies.

- Finally, in view of the absence of literature related to courtroom settings, a byproduct of the primary objectives is to obtain a better understanding of the courtroom as a behavior setting.

3.2.2 Possible by-products of the study

The attempt to integrate evaluation data with as-built building data opens up several other potential areas of outcomes. Some of these areas, too, have been a subject matter of debate and discussion in academic journals and literature. References to such discussions have been intentionally kept out of the main body of this thesis in the interest of clarity. Chapter 7 and the concluding chapter includes discussions on those issues, which includes:

- Adding substance to the ISO-STEP building model.
- The possibility to create a medium for greater interaction between researchers: a way to supplement traditional medium of communications that has been chiefly through the print media, conferences, and/or personal communication.
- The possibility to create a medium for a rigorous and shared representation of abstract concepts and constructs: an area that has been exclusively restricted to the print media. Technology may, in the long run, assist in creating better means of shared representations.
- The possibility to create a system that enhances traditional research methods like meta-analysis: meta-analysis has traditionally depended on multiple research

results. The very essence of creating an integrated data model begins to suggest potentials for this particular type of analytical method.

3.3 Research significance

This study addresses the issue of information support in the building industry. As discussed earlier, support mechanisms for portfolio management are already under progress. The study addresses another vital aspect of building procurement: early design and design review. The outcomes of the study address several areas of debate and discussion in literature, including:

- The study addresses the increasing urgency in feeding EB knowledge to the design decision-making phases. It provides an avenue for knowledge dissemination, and a source of supplementary knowledge to support decision-making during design and design review.
- Provide information to support decision making in the design and design review phases. Evidence-based design is an area witnessing wider applications in design practice.
- Create a medium to enable performance-based design and procurement - a movement that is increasing in importance in the building industry worldwide.
- Create a system that supports real-time discovery process by enabling hypothesis generation and testing that could pull together aspects of the physical, social, and cultural environment into a single analysis, based on the most up-to-date data. A

significant byproduct is an increased precision of predictions in design decision-making.

- Data inputs from buildings-in-use provides valuable support towards developing meaningful performance indicators. The study enables a true coupling of knowledge generation and support in the EB and engineering domains that has hitherto developed in a parallel but unconnected fashion. Since both domains are crucial to the design of successful settings, the bridging of the domains through the conceptual modeling approach is of particular significance.
- Since the data is time-coded, over time, the system will begin to provide feedbacks on historical trends, a key area of study in EB research. Cultural, social, and technological changes will also be reflected in the data.
- Finally, the study creates a body of knowledge about courtrooms. The current absence of knowledge about courtrooms makes this study important to researchers in EB as well as building engineering.

3.4 Research method

The methodology adopted for this study has six major phases. This section outlines the main phases in brief. Subsequent chapters deal with the works in each phase in greater details.

Formal knowledge on courtrooms is not widely available in academic literature. The first phase of the study involved obtaining a working understanding on courtrooms, and the

tasks performed in courtrooms. Courtrooms were targeted owing to several reasons.

Courtrooms have well defined tasks. They are relatively small to keep the modeling effort simple, yet have sufficient functional complexity to involve a wide range of tasks and issues. Finally, the investigator had access to courtrooms at both federal and state level.

Information about courtrooms was gathered from two types of sources. One source constituted the numerous brochures and pamphlets available about courtrooms and courthouses, and other government publications. The second source involved a thorough observation of courthouses and courtrooms through personal visits, and interviews with key users of courtrooms. The CourtsWeb project, in the College of Architecture at Georgia Tech, provided a good opportunity to learn about this domain. Visits to six courthouses as part of the CourtsWeb project offered an opportunity to observe the setting, interview key participants, and observe courtroom proceedings in session. In addition, the federal courthouse in Atlanta, Georgia, was studied in a similar manner. Interviews with key participants in the Atlanta courthouse were a significant source of information. Users interviewed in the seven courthouses included judges, court executives, courtroom deputies/clerks, court reporters, security personnel, and lawyers.

The interviews and observations suggested several important factors that are key to courtroom operations: physical factors including the size of courtroom spaces, and size and location of courtroom elements; environmental factors including lighting and acoustics; and security. Among the environmental factors are the domain of lighting and acoustics. Literature on lighting and acoustical factors influencing task performance was subsequently surveyed to identify important variables that need to be included in the

study. The result of this step identified physical and environmental variables that could influence the performance of courtroom tasks and proceedings. Conclusions drawn from the observations and interviews were validated by sending the draft to two knowledgeable persons in the field, for review and comments.

Works conducted in the first phase helped identify areas that need to be excluded to keep the study manageable. It was also necessary to draw the boundaries within which the model was to be defined. Phase I and II are elaborated in detail in chapter 4.

The next major phase was to outline the variables that are targeted for the study, and develop operational definitions of those. The results of the first two phases helped identify the physical, environmental, and other variables that needed to be included in the study. Variables and their operational definitions are elaborated in Chapter 5.

Data were collected through two separate but parallel procedures.

- POE study of courtrooms: a questionnaire was developed to collect data from courtroom users (see Appendix III, section 3.1 for the questionnaire used in this study). The questionnaire, data collection protocol, and the instruments used for data collection are elaborated in chapter 5.
- Collection of physical and environmental data from the settings that were being evaluated. A data collection protocol was developed for this task (see Appendix III, section 3.2 for the data collection protocol used in this study).

Physical and environmental data on courtroom settings was collected from 31 courtrooms in 16 courthouses. A total of 155 questionnaires were distributed among judges, deputies/clerks, court reporters, district attorneys and court security staff. Ninety three questionnaires from 26 courtrooms in fourteen courthouses were received by mail. The overall response rate works out to 60%. Details on the sample and the data are discussed in chapter 5.

A conceptual model was developed in parallel with the questionnaire and data collection protocol, once the variables were identified. The complete model, which was developed using EXPRESS-G syntax and notations, is described in Chapter 6. A database was developed to reflect the semantics of the conceptual model, using MS ACCESS software.

Figure 3.1 depicts the various phases of the study described above. Chapter 4 begins with elaborating the first phase of the study, which involved an exploratory study of courtrooms as work settings, and subsequently discusses the literature review conducted to identify factors that are considered influential in visual and auditory tasks.

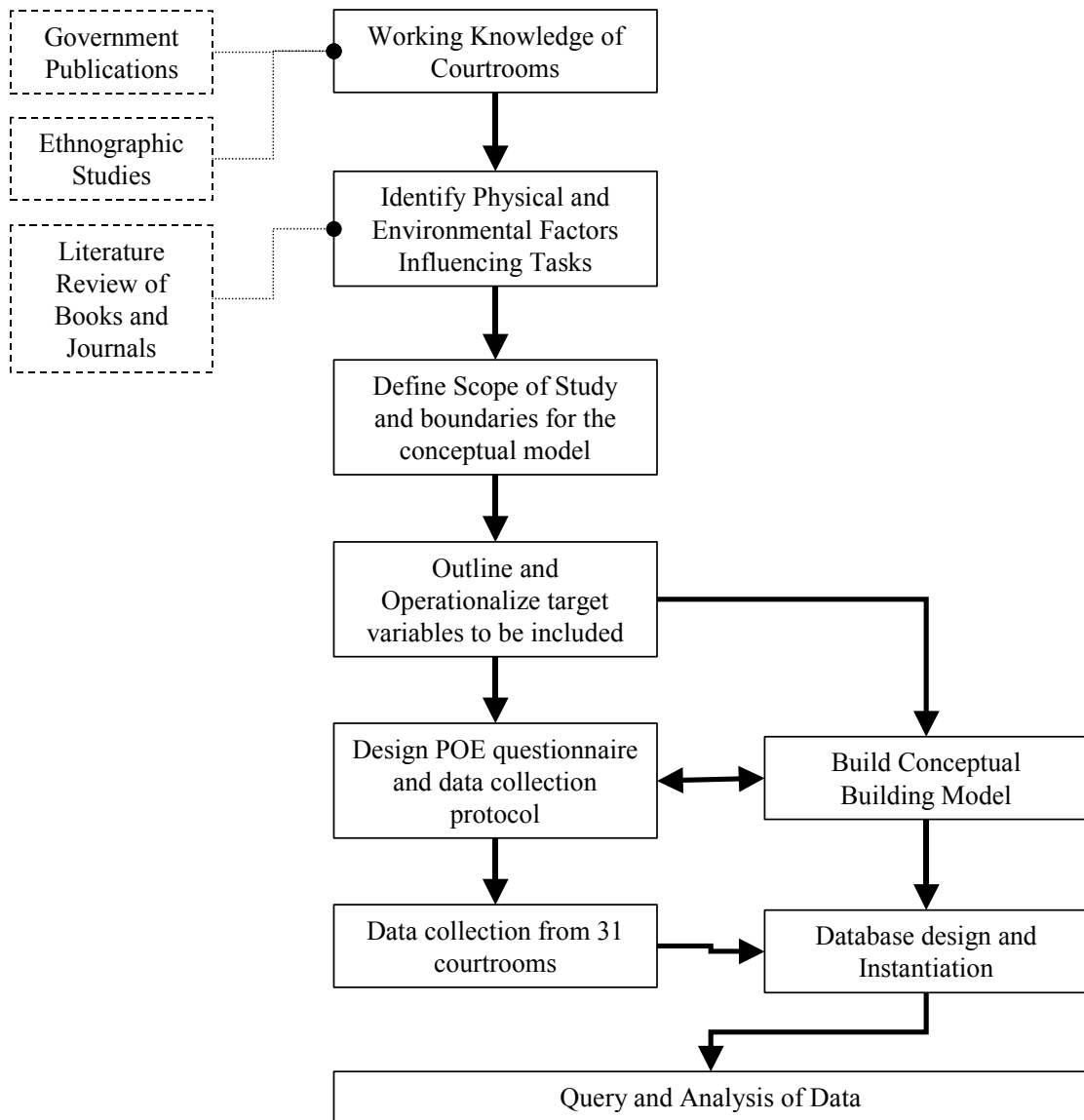


Figure 3.1: Flowchart depicting the major phases in this study.

Chapter 4

Courtrooms and Courtroom Tasks

In this chapter an understanding of courtrooms as work settings is developed. The structure of the judicial system in the United States is reviewed, along with a characterization of the major phases in typical civil and criminal cases, key tasks performed by courtroom users, and elements of the built environment that are hypothesized to influence courtroom performance. The chapter includes:

4.1 Introduction

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4.1 Introduction

In order to provide the most holistic perspective about courtrooms, courtroom users, and tasks, it is essential that courtrooms be viewed within a general framework of the judicial system in the United States. Most of the available literature on courthouses and courtrooms in architectural books and journals deal with courthouses as isolated cases. Descriptions of courthouse as a building type are not available from existing literature. EB issues related to courtrooms and its users are also not widely published. Psychological and sociological literatures on courtrooms are generally focused on relationships between psychological and personal variables, and case outcomes (whether a case is won or lost; whether a person is convicted or not), which are topics unrelated to this dissertation.

In the general absence of courtroom related literature in books and journals, the contents of the first section are derived from two types of sources. Pamphlets and brochures published by the judiciary (cited later at pertinent locations such as Center, 1988), the U.S. Courts Design Guide (AOUSC, 1998), along with descriptions from a varied source of courthouse websites (cited later at pertinent locations), constitute one type of source. The second source of information is from personal observation of courtrooms and court proceedings, and interviews of court personnel covering about 24 courtrooms in seven federal courthouses. The method included ethnographic study of courtroom settings, to understand processes and tasks. The key steps included:

- Observation study of courtroom during operation in all major phases of court proceedings: pretrial procedures, jury selection, hearing and sentencing.

- Unstructured discussions with courtroom/courthouse users to understand nuances that may not be obvious during observation.

Information about courtroom tasks and procedures were derived from site visits to seven courthouses, including the federal courthouses at St. Louis MO, Omaha NE, Greeneville TN, Corpus Christi TX, Cleveland OH, Hammond IN, and Atlanta GA. People interviewed during the visits include the judge, courtroom deputy/clerk, court reporter, security staff, and attorney. All courthouses were visited during the year 2002 and 2003.

Notes from observations and interviews were subsequently analyzed to:

- Understand major phases of courtroom proceedings.
- Outline various tasks conducted by each user in a courtroom.
- Understand the parameters of a courtroom that appear to influence court proceedings and task performance.

The following discussions start with a sketch of the justice system of the United States, and proceed to outline some of the hypothesized important physical and environmental variables in courtroom settings.

4.2 The judicial system

The federal nature of the United States constitution distributes the charge of justice deliverance between the federal and the state governments. There are, thus, two sets of court systems in the United States: the federal courts system, and the state courts system (county and municipal/city courts are considered to be within the state system for this

discussion). The state courts have general, unlimited jurisdiction over settling dispute between parties, whereas federal courts handle only certain types of cases. In both systems there are courts where trials are conducted, and there are courts that are specifically reserved to hear appeals from the trial courts. In both systems the apex court is the Supreme Court, although the United States Supreme Court is the highest judicial authority in the United States whose decisions cannot be appealed. Owing to the general jurisdiction of the state court system, the state courts have various different kinds of specialized courts that handle specific types of cases. Civil and criminal cases are common case types to both systems. In addition, the federal courts hear specialized cases like bankruptcy cases, which are unique to the federal court system. The state courts too (including some courts at county level), since they affect the day-to-day life of citizens, have several specialized functions like juvenile and probate cases. Some of the court proceedings do not include trials, and vary significantly in requirements from trial courts. Owing to the differences between the two systems, the following sections describe the two systems separately.

4.2.1 The federal courts system

As pointed out above, federal courts deal with limited types of cases (limited jurisdiction) that include disputes that are related to the federal constitution as well as laws passed by the U.S. Congress. Generally, cases heard in a federal court have the federal government as one of the parties. Those case types include cases involving violation of the constitution, federal law, diplomats, cases concerning incidents at sea, and bankruptcy

cases. Federal courts also hear cases related to disputes between parties from different states. (The material below is compiled from several sources. For more detailed information see AOUSC, 1998; Center, 1988, Undated; U.S.Courts, 2003a, 2003b, 2003c, 2003d).

There are three types of federal courts: the United States District Courts, Court of Appeals, and the Supreme Court of the United States. In addition, there are several federal agencies, administrative agencies, and courts within the federal circuit that are also considered a part of the federal court system. There are 94 judicial districts that cover the whole of the United States. Each judicial district has a federal district court. District courts are the trial courts of the federal court system. Typical civil cases heard by the district courts include discrimination cases, cases involving actions involving benefits from a government program (like social security), and business monopoly cases. Typical criminal cases heard by the federal district courts include some types of robbery (such as bank robbery, that violate federal law), and drug cases. Civil and criminal matters involving interstate activities also fall within the purview of federal courts. In addition, district courts hear bankruptcy cases. The bankruptcy courts have their own (special) bankruptcy judges as well as administrative structure, but operate as a specialized unit within the umbrella of the district court system. District courts conduct court proceedings in generally five types of courtroom settings. Special Proceedings (or ceremonial) courtrooms and District Regular (or standard) courtrooms are the trial courtrooms. Magistrate Judge courtrooms are places where preliminary hearings for criminal cases, and some types of civil trials are heard. Bankruptcy courtrooms are settings where

bankruptcy cases are heard. Grand Jury rooms are used to conduct initial hearings in some criminal cases, although judges are not involved in grand jury hearings.

Traditionally, a courtroom is assigned to a single judge. More recently, however, some courthouses have initiated the practice of sharing of courtrooms by judges. Further, even in the traditional type of courtroom allotment, different types of courtrooms, in some cases, are being designed with identical specifications to incorporate flexibility in use for multiple case types (for instance, bankruptcy courtrooms are being designed with jury boxes to accommodate district courts proceedings if necessary). In addition to the District Courts, there are two special trial courts, which hear cases from the entire country. One is the Court of International Trade that deals with cases involving international trade and customs, and the other is the Court of Federal Claims that deals with issues involving claims of money damages against the United States, federal contract disputes, unlawful property acquisition, and other claims against the state governments (U.S.Courts, 2003c).

The 94 federal judicial districts are contained within 12 regional circuits. Each regional circuit includes a Court of Appeals. The courts of Appeals, as the name suggests, are the appellate courts that review cases heard in the district courts, as well as those from the federal administrative agencies. In addition to the 12 Courts of Appeals, the federal circuit has its own Court of Appeals in Washington, D.C., and it deals with limited types of cases (involving patent laws, and cases decided by the Court of International Trade and the Court of Federal Claims (U.S.Courts, 2003b) from the entire country. The Court of Appeals has two types of settings. A panel of three judges hears most cases. On certain

occasions, at the request of the parties involved in a case, all appellate judges may sit together during the review. The former takes place in what are called the Panel Courtrooms, and the latter takes place in En banc Courtrooms. These proceedings do not involve jurors, witnesses or court reporters. The principal task is to review the record, transcripts, and lawyers' briefs from the lower courts and listen to the legal (oral) arguments from the lawyers of the parties involved. Decisions are made based on majority vote among the judges, and dissenting opinion is also recorded.

The Supreme Court of the United States is the highest court that hears (some of the) cases from the federal court of Appeals as well as state Supreme Courts. The most fundamental function of the Supreme Court is to clarify the interpretation of law when there is any disagreement regarding it, and to decide on the constitutionality of a law or action. Supreme Court decisions regarding interpretation of the law are followed through in all inferior courts when interpretation of law is warranted. The Supreme Court also enjoys the power of judicial review; a power that enables the court to declare that a certain law passed in the legislature is in violation of the constitution. The outcome of a judicial review is final in the sense that only a subsequent decision of the Supreme Court, or a constitutional amendment could change it. Unlike the inferior courts in the federal system, all nine judges of the Supreme Court hear every case. Figure 4.1 below illustrates the federal courts system.

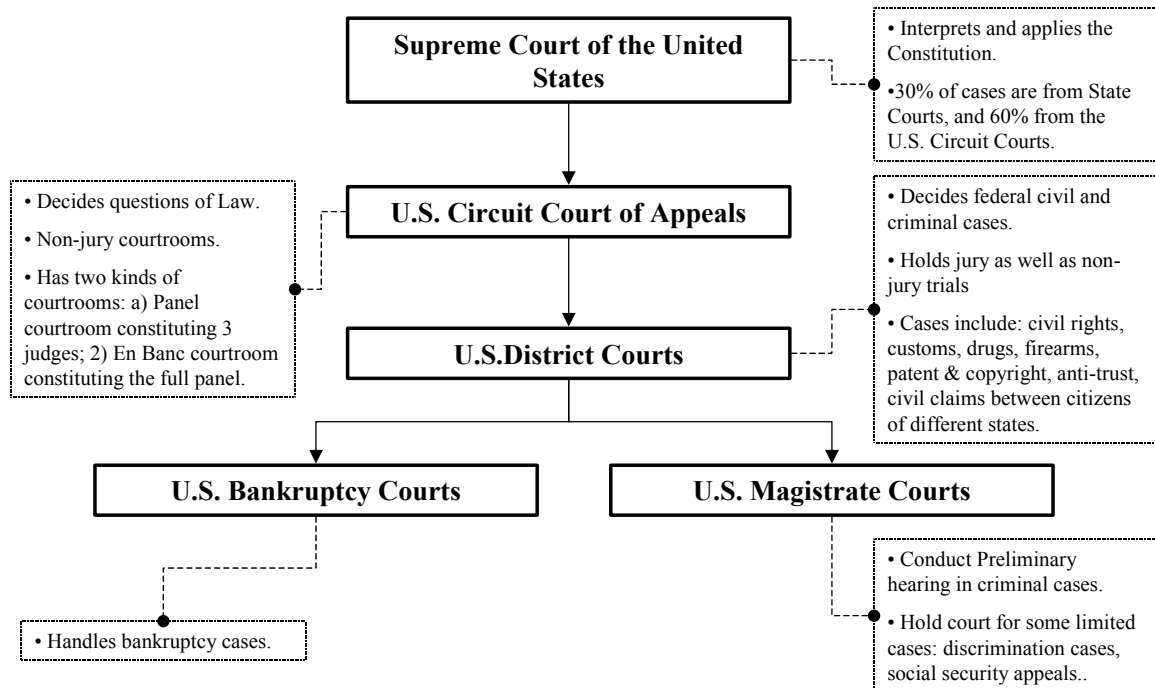


Figure 4.1: The Federal Courts system in the United States.

4.2.2 The state court system

State governments, as well as county and city governments within a state, establish state courts. The system varies marginally from state to state, but shares a common general structure. The discussions about state courts here are specific to the State of Georgia, as an example. The materials here are compiled from several websites on Georgia courts (Georgia, 2003a, 2003b, 2003c, 2003d, 2003e, 2003f, 2003g, 2003h). The state Supreme Court is the apex body that deals with cases involving the interpretation of state laws and constitutions. The Supreme Court, along with the state Court of Appeals, constitutes the appellate judicial body in a state. The state Superior Courts are the counterparts of the Federal District Courts, and are the main trial courts. Below the Superior Courts are a wide variety of courts that deal with limited jurisdictions or specialized jurisdictions. At

the top of the ladder is the state Supreme Court. Such courts have exclusive appellate jurisdictions over cases that include the state constitution, U.S. constitution, construction of a treaty, constitutionality of laws and ordinance as well as constitutional provisions, and election issues. They also have jurisdiction over cases related to land title, equity, wills, habeas corpus, mandamus, prohibition, quo warranto, divorce and alimony, and cases involving death sentences. They hear cases certified from the court of appeals and some superior court cases. Case reviews are conducted en banc and outcomes are dependent on majority opinion (Georgia, 2003h).

The Court of Appeals reviews cases from the Superior, State, and Juvenile Courts, including, among others, all criminal cases (other than capital felonies), cases involving administrative laws, and civil claims. In some type of cases the state Supreme Court has reserved jurisdiction, and those cases are not reviewed by the Court of Appeals. A panel of three judges reviews the cases, and panel decisions are generally final other than in cases of dissenting opinion, when the full court reviews such cases. Unresolved cases are referred to the state Supreme Court for review (Georgia, 2003a).

The state Superior Courts are the main trial courts in the state system. Superior Courts have a general jurisdiction. They have exclusive authority over cases involving felony, divorce, equity, land title, declaratory judgments, habeas corpus, mandamus, quo warranto, and prohibition. They have the authority to rectify erroneous judgment made by some inferior courts. State court systems divide a state into judicial circuits, and each judicial circuit has one or more Superior Courts (Georgia, 2003g). Unlike the Federal

District Courts, a Superior Court courtroom may or may not be assigned to a single judge. In many instances judges serve more than one Superior Court, which are usually located in county headquarters.

Below the Superior Courts, are a variety of courts with limited jurisdiction or specialized jurisdiction. County or city governments establish such courts. In Georgia such courts include the State Court, Magistrate Court, Juvenile Court, Probate Court, Municipal Court and other Special Courts. A similar list of lower courts can be found in other state court systems. State Courts are courts of limited (countywide) jurisdiction and may hear all misdemeanor cases including traffic, and civil actions. They also hold hearing for search and arrest warrants, and hold preliminary hearings (Georgia, 2003f). Magistrate Courts are another kind of limited jurisdiction court that looks into cases involving civil claims of less than \$15,000, some minor criminal offences, distress warrants, dispossessory writs, county ordinance violations, and check frauds. They also hold preliminary hearings, summonses, arrest and search warrant, and bail hearings. Magistrate courts do not hold jury trials (Georgia, 2003c). Juvenile Courts deal with the protection, welfare, security and interest of children. They have exclusive jurisdiction over delinquent and deprived children aged 17 and 18 years or less, respectively. Their jurisdiction includes cases involving traffic violations, enlisting in military service, marriage consent, and cases involving interstate juvenile compacts. In cases dealing with capital felonies, custody, child support, and termination of parental rights, juvenile courts share jurisdiction with superior courts (Georgia, 2003b). Probate Courts are another kind of specialized court that deals exclusively with wills, estate administration, guardian

appointment, and involuntary hospitalization of incapacitated adults. They also administer oath of office, issue marriage licenses, hold habeas corpus hearings, and may hold preliminary hearings in criminal cases. In counties without State Courts, some of the works of the State Court judges are performed by Probate Court judges (Georgia, 2003e). Finally, incorporated municipalities create Municipal and other special courts. These courts do not have a common naming system across municipalities, and the jurisdiction varies between the courts. Generally their jurisdiction includes cases involving violation of municipal ordinances, issuance of arrest warrants, preliminary hearings, and similar matters (Georgia, 2003d). Unlike the federal courts where courtrooms vary in design and setting depending on court type (district, magistrate, bankruptcy, etc.), a field study of the state courthouses in Georgia revealed that the same is not true in the state court system, although some richer and more populated counties have built new judicial centers that have different courtrooms for Superior, Magistrate and other courtroom types. Figure 4.2 illustrates the state court system in Georgia.

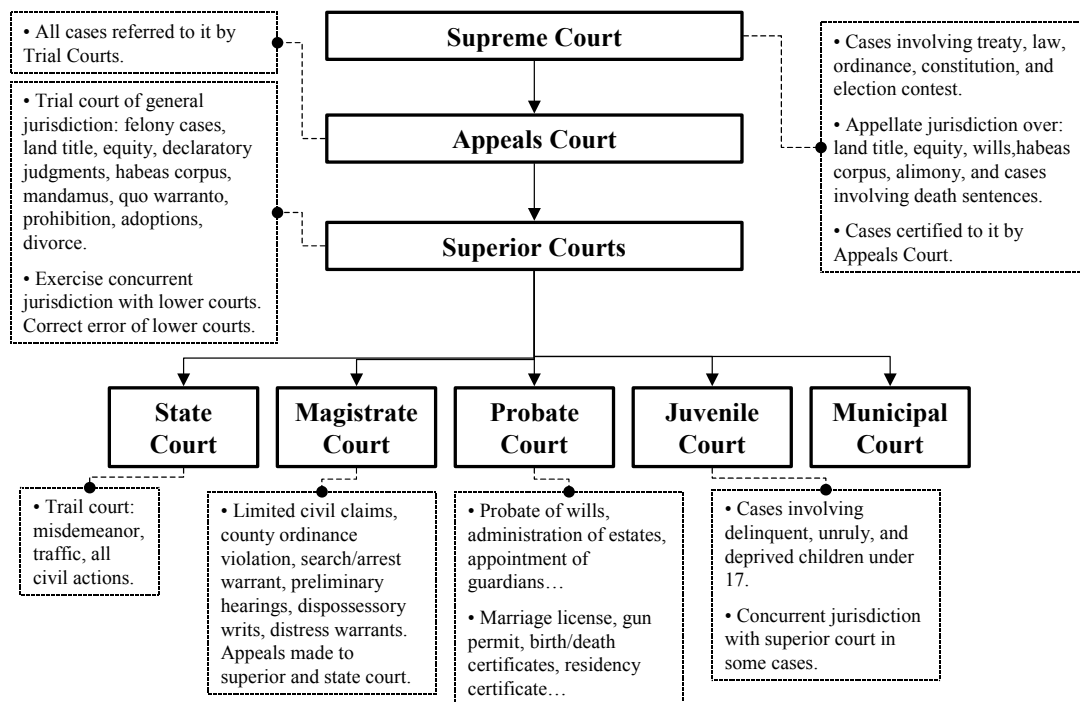


Figure 4.2: The State Courts system in Georgia.

This dissertation focuses on trial courtrooms, and the subsequent discussions pertain to courtrooms that hold all or some of the proceedings involving trials. Such courtrooms include the Federal District Regular courtroom, Federal Special Proceedings courtroom, the Federal Magistrate Judge courtroom, and the state Superior Court courtroom. The first step in understanding the requirements of trial courtrooms is to understand the case flow in typical civil and criminal case.

4.3 Case flow in trials

The processes outlined here are most common for federal courts. With some variations, cases in state courts follow a similar process. The following materials are compiled/extracted from Federal Judicial Center (Center, 1988), personal observations, and transcripts of interviews. Proceedings in a courtroom are only a part of the proceedings involving a civil or criminal case. The Grand Jury room, Magistrate Judge courtroom, and the judge's chambers are some other settings where some proceedings take place. Many cases also get settled before going to trial. Moreover, a trial may or may not involve a jury (jury trial versus a bench trial) and courtroom tasks (more specifically of the judge) changes substantially depending on the type of trial.

A district judge handles most civil cases at the federal level. Magistrate judges are allowed to handle cases involving discrimination and social security appeals. Parties in a civil case are called plaintiff and defendant (as opposed to criminal cases where the parties involved are the government and the defendant). A civil case starts with the plaintiff filing a complaint with the clerk of the court. The complaint is then served on the defendant (mentioned in the complaint), to which the defendant files an answer. After 30 days of the filing of the answer, a process of discovery begins. The 30-day gap is provided to enable resolution of the case out of court. Judges are not involved in this process. The discovery process, part of the pre-trial activity, enables the lawyers from both sides to learn about the case in detail. The parties produce a list of documents and witnesses they intend to use in the proceedings. This enables each party to learn about the

case and the opponent's strategy in detail. A district judge gets involved in this process only if there is dispute related to the documents. Typically, the discovery process lasts about four months, although it is not infrequent that parties request more time for the process, which is generally granted. In many cases parties agree to settle cases without trial after the discovery process. In the absence of such resolutions, twenty days after the close of the discovery, the defendants could file motions for summary judgments for the dismissal of the cases. The typical argument is lack of evidence. A pretrial order is required to be filed within 30 days of close of discovery. The order lists the position of each party on the case, the list of witnesses to be produced, and the list of exhibits to be produced. On the conclusion of the filing of the pretrial order, the case is declared as ready for trial. A pretrial conference (the last step before trial begins) is held at this stage. The conference agenda includes agreeing on the issues involved in the case and those not in disputes, finalization of the witness list, list of evidence, and any remaining issues. At this stage the judge also explores the possibility of settlement without trial. The courtroom proceedings begin after the pretrial conference.

A misdemeanor criminal case starts with a complaint lodged by the U.S. Attorney, which then proceeds to the indictment (a statement of formal accusation). Alternately, it could start directly with an indictment by a Grand Jury, which usually happens with felonies. A Magistrate judge handles the case during these phases. A successful indictment leads to arraignment where the defendant pleads guilty or otherwise. When a defendant pleads guilty a trial is not necessary, and the process goes to the sentencing phase. When defendants plead not guilty, the court has to try the case and find the defendant guilty or

not. After arraignment the case is assigned on a rotating basis to one district judge and one magistrate judge. The magistrate judge takes decisions on bond matters and handles pretrial motions. On the conclusion of pretrial motions a pretrial conference is held where the magistrate judge rules on the motion. In certain areas where the magistrate judge lacks authority the judge may refer the matter to the district judge. Similarly, the magistrate judge may refer the whole motion to the district judge. The magistrate judge may also set an evidentiary hearing. The case, at this stage, is declared ready for trial and the district judge conducts all subsequent proceedings.

Courtroom proceedings are very similar for civil and criminal cases. In case the parties request a bench trial, the judge gets the fact-finding task. If the parties request a jury trial, the first step in a trial involves the selection of jurors, typically from a population of registered voters or driver license holders. The number of jurors needed vary depending on the case; civil cases need eight jury members and criminal cases need 12. In addition, one or two alternative jury members are also selected to take into account situations where a jury member becomes unavailable in the middle of a trial. The final list of jurors is arrived at after a session where the judge and the lawyers question each juror to determine whether the juror is prejudiced or not. The larger pool of jurors could contain as many as 30 people or more and sufficient seating in the public seating area of the courtroom helps the process. The process becomes more streamlined when potential jurors are physically separated from the public, family members, press and any other party that might decide to watch the proceedings. Insufficient gallery seats sometime forces judges to seat potential jurors in jury boxes or in general well areas. In some cases

judges move to courtrooms with larger gallery seating to select jurors, and subsequently move back to their courtrooms for other proceedings. More space around the attorney tables also help, since the attorneys move their seats to be able to face the jurors for questioning. Reporters may move temporarily from their assigned seats to be better able to record the proceedings, in many instances. After the questioning session by the judge and the lawyers, the jurors are moved out of the courtroom temporarily, during which the striking process takes place. When public waiting spaces are available outside the courtrooms it aids the selection process during this phase by providing the jurors a place to wait and relax close to the courtroom. After the jurors are moved out of the courtroom, lawyers of the parties involved in the dispute confer among themselves (privately) to decide on whom to strike. Striking is a process where jurors are eliminated from a larger pool, and different judges adopt different methods for this. Striking is sometimes called out by the lawyers of the parties involved, where as in other cases a paper with the list of jurors is circulated between the parties. In federal cases, for instance, the government is allowed six strikes and the defendant ten strikes. Once the final list of jurors is arrived at, the selected jurors are called out into the jury box and are sworn-in by a courtroom deputy. The judge, subsequently, gives basic instructions to the jurors.

The next major phase in a case involves opening statements, where the parties present to the jury (or the judge in a bench trial) their versions of the dispute, and what they expect the evidence to show. The government or the plaintiff is given the first opportunity followed by the defendants.

A process of cross-examination starts after the opening statement. This process enables the parties to present evidence in support of their contention. Evidence typically includes live testimony by witnesses, deposition testimony (when witnesses are unable to come to the courtroom), documentary evidence, and objects. The government or plaintiff presents their evidence first, which includes direct examination of witnesses, as well as cross-examination of the witnesses by the defendants. Between the presentation by the government/plaintiff and the presentation by the defendant a break is provided after the first party rests its case. In most cases defendants or their attorneys move for dismissal of their cases or parts of their cases during the break, citing insufficient or impertinent evidence. This process is conducted outside the presence of the jurors. After the break the defendants present their evidence in a similar manner. Frequently, judges and lawyers engage in private discussions commonly referred to as sidebar discussions, in the presence of reporters, to discuss matters related to the evidence presented. The defendants, after resting their cases, typically make another motion for dismissal of their cases. In criminal cases the government then presents a rebuttal, when the defendants' evidence substantially weakens the government's case. The government, subsequently, is allowed to present further evidence and witnesses to bolster their case.

Closing arguments and Charge conferences follows the conclusion of the presentation of evidence. The Charge conferences are conducted in the absence of juries. In these conferences the lawyers present to the judge what they presume the issues of law regarding presumption of innocence, testimony by the defendant, and similar issues. During the closing argument the government or the plaintiff goes first, followed by the

defendants. In some occasions the government gets a second opportunity for closing arguments.

Following the closing arguments the judge provides instructions to the jury on the law. Some judges reverse the order by instructing the jury before the closing argument. The jury is subsequently led to the jury deliberation room, with written instructions in some cases. Once inside the deliberation room, any questions by the jurors are provided in written form to a security officer who passes them on to the deputy, who in turn passes them to the judge. The judge provides written responses to the jury through the same route. In some cases, if further instructions are needed to the jurors' questions, jurors are brought back into the courtroom. The same is true on occasions when the jurors go back to the courtroom to review video evidences. Jurors in the deliberation room get access to the verdict form, copies of the indictment, all case evidences, copies of jury instructions, and video or audiotapes.

On conclusion of the deliberation the jury returns to the courtroom with a verdict. During this phase the attorneys can poll the jurors in case they have any doubts about the unanimity of the verdict. Further, during this phase the lawyers can move for mistrial citing irregularities. In case of mistrials the jurors are excused, and the process restarts using a new juror pool. Otherwise, verdicts are read aloud to all parties. If the defendant is not found guilty, an order of acquittal is issued. In case of a guilty verdict in criminal cases, a date is set for sentencing.

Subsequent phases are held without jurors. In civil cases the judge decides on the amount of damage to be paid or the kind of service to be performed, leading to the conclusion of a typical civil case. In criminal cases the probation office prepares a pre-sentence report and sends it to the attorney for objections. The report is then rectified and a final report prepared and presented to the judge. On the date of sentencing, the judge imposes a sentence. That leads to the conclusion of a typical criminal case. Figure 4.3 and 4.4 illustrate the key phases of a typical case.

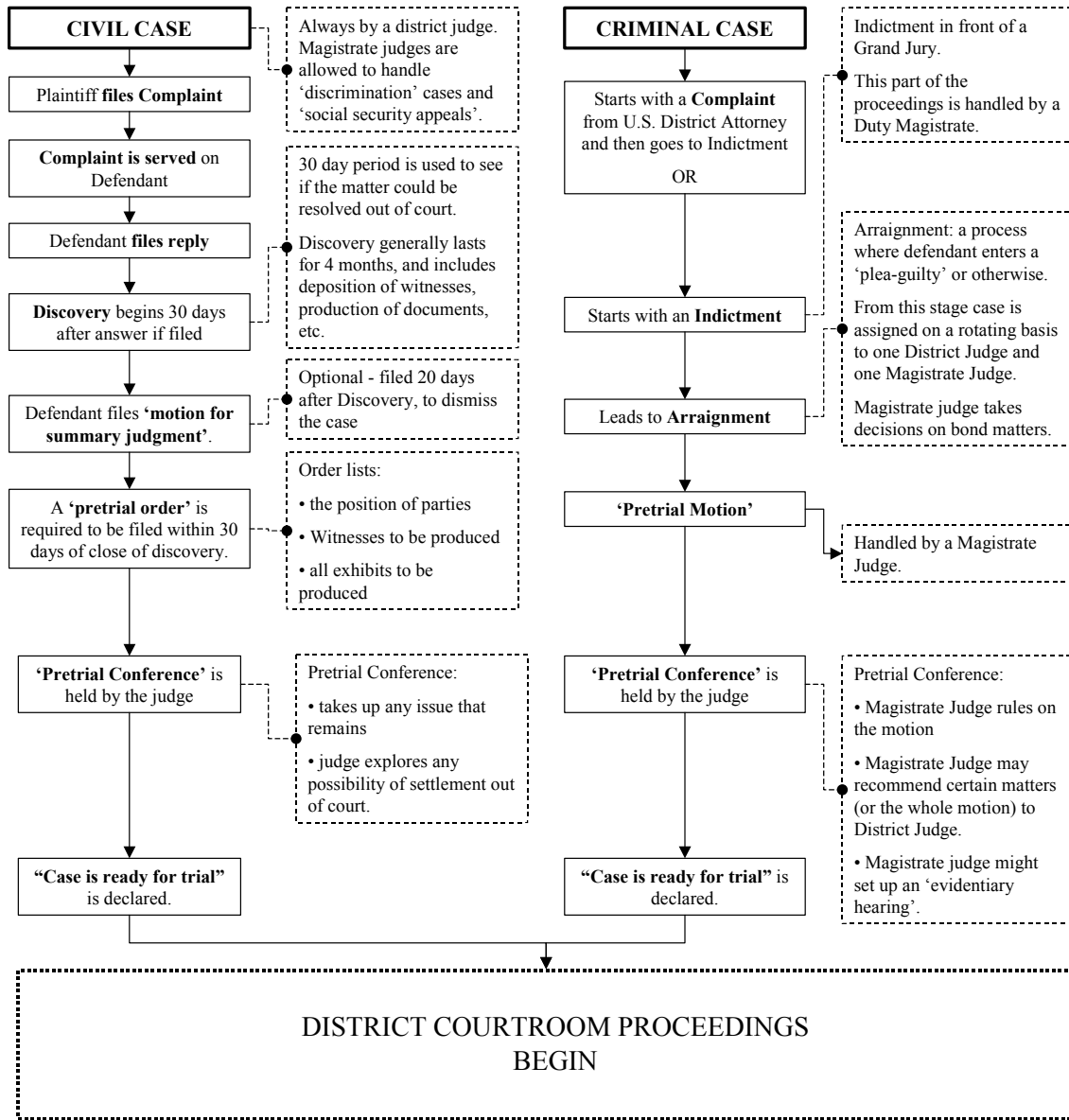


Figure 4.3: Typical case flow before trial.

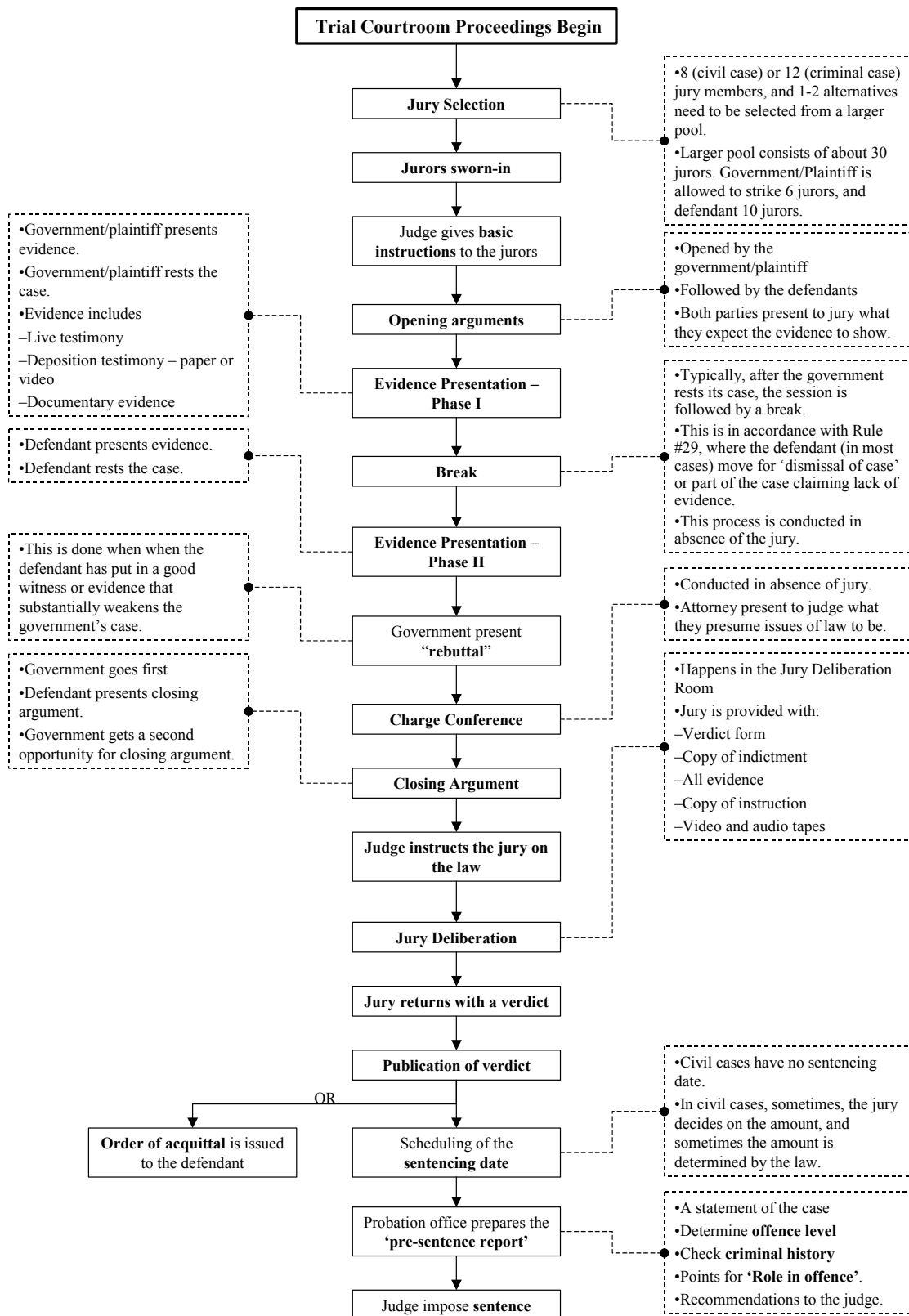


Figure 4.4: Typical case flow during trial.

4.4 Courtroom tasks

Different actors in the courtroom (judge, deputy, reporter, security, jury, attorney) perform different types of tasks. The tasks they perform, however, do not vary much and a subset of common base level tasks can be identified. A few non-typical tasks define the uniqueness of each actor. In general, the most crucial requirements during a courtroom proceeding include:

- The ability to see clearly and perform visual tasks.
- The ability to hear clearly when spoken to by other people, and the ability to discuss issues with others without being overheard, in many circumstances.
- The ability to perform each phase of the proceeding without undue disturbance or obstructions - smoothness of task flow.
- Ensure safety and security of all people, proceedings/function, and objects (such as evidence) throughout the court proceedings.

Out of these four aspects, safety and security considerations are not considered in this study (considering difficulties in collecting security related data). Within each requirement area outlined above, the actors in a courtroom could be associated with the following major task types.

Judges have four types of functions: preside over proceedings and maintain order, rule over admissibility and legality of evidences, give instructions to the jury, and in case of a

bench trial, engage in fact finding. Conducting preliminary hearings are also part of the judge's task. A judge's tasks may be listed as the following:

- Read from legal documents (all legal documents follow prescribed standards for paper size, and font type, size and color).
- Read from electronic projections (monitors, larger screen projections); examine deposition testimony.
- Examine documentary evidence.
- Monitor facial expressions (witness, jury...).
- Take notes.
- Listen clearly to others' spoken words (attorney, jury, witness...).
- Verbally address other actors within the courtroom.
- Discuss with acoustical privacy.

The function of the courtroom deputy or clerk includes (courtroom deputies in the federal system are different from deputies in the state system, who perform security functions; Clerks of Court conduct parallel functions in the state system): administer oath to witnesses, catalog evidences, register schedules, and ensuring that the proceedings run without obstructions. The deputy does all the paper work involved in a case. The tasks of a deputy may be listed as follows:

- Read from legal documents (all legal documents follow prescribed standards for paper size, and font type, size and color).
- Read from electronic projections (monitors, larger screen projections).
- Catalog evidence.

- Take notes.
- Listen to others' spoken words (attorney, jury, witness...).
- Verbally address other actors within the courtroom.
- Discuss with acoustical privacy.
- Receive materials from attorneys and others to pass to the judge, and perhaps to witnesses and jurors.

The court reporter records all proceedings in the courtroom. Different devices are used, including stenographic machines, voice masks, tape recorders, and simultaneous transcription equipment. In order to maintain the accuracy of the transcripts they need to be able to hear everything that is said clearly, and preferable be able to see the face of the person speaking. The tasks of a reporter may be listed as follows:

- Listen clearly to others' spoken words (attorney, jury, witness...).
- Monitor facial expressions (for better speech comprehension).
- Read from electronic projections (monitors, larger screen projections).

The lawyer's main function is to extract facts and portray their position in a manner that may result in favorable outcomes for their clients. They have a prominent role to play throughout the case. The range of tasks they conduct may be listed as:

- Read from legal documents (all legal documents follow prescribed standards for paper size, and font type, size and color).
- Read from electronic projections (monitors, larger screen projections); examine deposition testimony.

- Examine documentary evidence.
- Monitor facial expressions (witness, jury...).
- Take notes.
- Listen clearly to others' spoken words (judge, jury, witness...).
- Verbally present information and convincing arguments to other actors.
- Discuss with acoustical privacy.

The security officers in the courtroom are in charge of maintaining law and order. They play a prominent role in presenting witnesses in custody, and guiding the jury members during jury selection as well as the trial. Their main tasks could be listed as:

- Read from printed documents.
- Monitor people in courtrooms.
- Listen to others' spoken words.
- Verbally address other actors within the courtroom.
- Escort criminal defendants in and out of the courtroom.
- Protect all court participants, including the public and defendants.

Finally, the jurors listen to the presentation of all parties and decide whether the defendant is guilty or not guilty of each charge. Their major tasks could be listed as:

- Read from electronic projections (monitors, larger screen projections); examine deposition testimony.
- Examine documentary evidence.
- Monitor facial expressions (witnesses).

- Take notes.
- Listen clearly to others' spoken words (attorney, witness...).
- Verbally address other actors (in some instances).

Description of the key phases in a case and the major tasks performed by each type of courtroom user is intended to provide a better understanding of courtroom design criteria (or requirements) that may influence the efficient conduct of courtroom tasks and proceedings. The following section addresses some of the design parameters that plausibly influence courtroom performance.

4.5 Courtroom design parameters

Three aspects of the case flow best capture the relationships among design parameters and courtroom proceedings. First is the difference between the trial phases, and the pretrial and post trial phases. A second major difference is between phases in a trial that are conducted in front of a jury, and those that are not. The third aspect is whether the trial is a jury trial or a bench trial. During the pretrial phases the judge and the parties involved try to reach a common understanding of the dispute involved. Those include the nature of dispute, what issues are disputed and what are not, the documents and witnesses to be produced (presided by a magistrate or district judge depending on the type of case). One of the main purposes of pretrial activities is to avoid wasting time during trial. Such types of activity probably need a conference type set up, where parties are near each other, and able to see all the others without much difficulty. The parties need to be able to

converse without unduly raising their voices, and should be able to pass documents without much effort. In addition, hearings for bonds, pretrial motions, and some other processes take relatively lesser time compared to the hearings that involves juries. Owing to the initial phases of the case, it is typical for large number of family members and other interested parties to gather in the gallery, which is in contrast to the trial phase where, barring high-profile cases, the gallery remains under-occupied in practice, while the large seating capacity serves a symbolic purpose of providing a sense of openness and citizens' access to court proceedings. More people in galleries entail more traffic into and out of courtrooms, and thus more potential sources of disturbances. The trial phase changes things considerably, especially in the case of jury trials. In a jury trial the judge assumes a supervisory role. The attorneys in non-jury situations focus their activities on the judge, whereas in the presence of a jury, the attorneys' focus on the jury. The jury box becomes the focus of attention, and the role of the judge is reduced to ensuring the legality and validity of the proceedings. Even in the case of a bench trial, the process of trial becomes a symbolic, public display of the justice delivery process, and a conference type set up probably does not serve well. The layout of the well, including placement, adjacencies, and distances between key elements (the bench, witness stand, jury box, lawyer tables, deputy station, reporter station, and the security station), as a result, influence the work within the courtroom, by supporting either a conference or supervisory requirement. As discussed in the previous section, all activities in a trial do not take place in front of a jury, and the presence or absence of a jury oscillates the focus in a courtroom between the bench and the jury box. Keeping these broad distinctions in

mind, the following paragraphs attempt to highlight some of the important variables in a courtroom that could be hypothesized to influence performance.

4.5.1 Courtroom shape

Courtrooms are generally found in rectangular-long (bench-public entry axis longer than second dimension) or square configurations. Some courtrooms are rectangular-wide (bench-public entry axis shorter than second dimension), circular or other shapes. The shape of the courtroom influences the way the furniture is arranged in the well and gallery (figure 4.5 shows the well and gallery area in a typical courtroom). Pretrial phases, needing a conference type set up, are probably more compatible with rectangular-long courtrooms, since such courtrooms offer ideal configuration for a conference-type furniture arrangement. Further, during some of the pretrial phases large number of people could be expected in the gallery (this is truer for state courts where the case load is considerably higher than the federal trial courts). A narrow well and a large gallery capacity that translates into a rectangular long courtroom, is probably an optimum shape for pretrial phases.

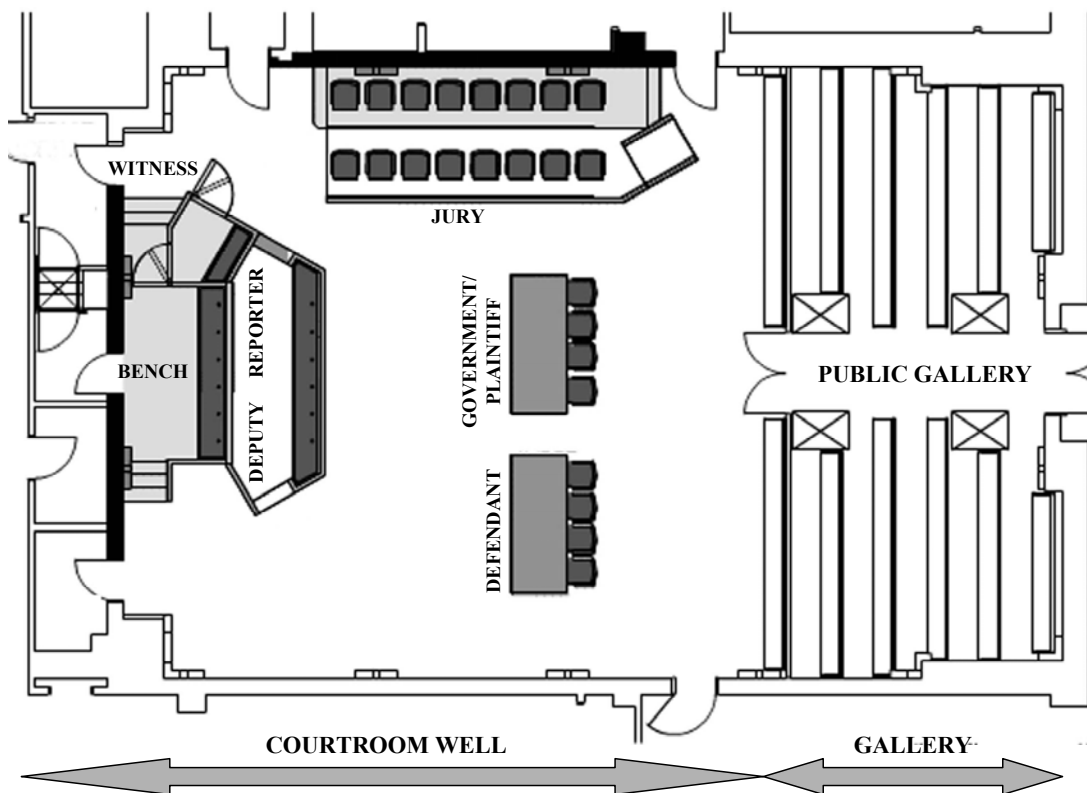


Figure 4.5: Spaces and actors in a typical courtroom.

On the other hand, the trial phases require a more supervisory role of the judge. Even in bench trials, the symbolic functions of the courtroom are much more intense during the trial phases as compared to the pretrial phases. Further, public in the gallery need to be close to the proceedings in the well, where long courtrooms may not be appropriate.

Sufficient space is required for the lawyers to perform their presentation of evidence and examination of evidence, which demands wider well area. A square or rectangular-wide courtroom would probably suit this aspect of a courtroom activity better as compared to rectangular long courtrooms.

Other shapes have been tried out for courtrooms. Square shaped courtrooms have been associated with democracy, where all parties appear to be of equal importance. Circular shaped courtrooms have been argued to induce a feeling of togetherness (Leers & Feiner, 2003). This raises the possibility that the length/width ratio (or the shape) of the courtroom as a whole plays a crucial role in supporting courtroom procedures.

4.5.2 Courtroom Size

From a purely symbolic viewpoint larger courtrooms, in addition to high quality finishes and furnishings, probably convey the authority of the State and the rule of law. Several functional requirements, nevertheless, also dictate the sizes. The necessity to hold multiple defendant trials in some courtrooms warrants larger well areas. A similar issue is whether to have a one, two or three tier jury box. Larger number of tiers in the jury box demand a wider well area, and hence a wider courtroom. Another issue that affects well size is the location of the deputy and reporter. When they are located in the front of the bench the well length increases; when located on one side of the bench the width of the well is affected. Similarly, decisions regarding how handicap accessibility is addressed affect the size of wells. Providing ramps in the well require considerably larger wells, as compared to lifts. Large well sizes reduce the intimacy with the jury, sought by the attorney. Small well sizes, however, begin to impact the smoothness in which multi-defendant trials are conducted. An important aspect of the well size also relates to symbolic functions. The perception of magnificence and awe provided by large volume and well area is felt necessary to convey the dignity of law and the importance of the

judicial process. A large well size suits the symbolic functions as well as the necessities for multi-defendant trials. However, as the well size increases, the intimacy between the parties reduces, not to mention the increasing distance between key players in the well. Many of the courtroom functions depend largely on how closely parties (judge, attorney, reporter) can read facial expressions. With increasing distances, one begins to lose that capacity.

The importance of the gallery capacity has already been described previously. During the jury selection process the capacity in the gallery affects the efficiency of the process through which jurors are selected. During pretrial procedures too, the capacity of the gallery dictates the number of people that can be accommodated, and influences the amount of noise generated from movement into and out of the courtroom. Also, if the gallery is undersized, people will have to sit uncomfortably close to each other; this may increase the likelihood of arguments and discontent.

A related aspect is the capacity of the public waiting area outside the courtrooms. Insufficient gallery capacity may necessitate people to wait outside the courtroom during pretrial procedures. During the jury selection phase, when the jurors are required to wait outside the courtroom (before the process begins as well as during the striking phase) the amount and quality of waiting area and amenities determine the degree of movement outside the courtrooms and, hence, the noise transmitted into courtrooms from the public areas outside. The lack of sound locks in many courtrooms can contribute significantly to noise transmission from public areas depending on the noise level. The design of public

waiting space varies considerably between courthouses and courtrooms. In the St. Louis federal courthouse public waiting area is devoid of any furniture. In contrast, the federal courthouse in Omaha has been designed with well-marked public waiting spaces with ample seating. In some courtrooms in the Greeneville federal courthouse, no space has been earmarked for public waiting. This is also true for many of the state courts where public waiting space is either not provided, or have insufficient or few furniture. This, hypothetically, could influence the efficiency of courtroom operations. It could also influence jurors and public attitudes, stress/anxiety, and negative behavior.

4.5.3 Location and design of courtroom elements

The location of some courtroom elements can significantly affect performance, symbolic or otherwise. A center bench location provides the much-required symbolic importance of the judge. It helps maintain the symmetry in the courtroom, and creates an axis with the gallery and entrance that adds to the symbolic function. On the other hand it creates unused spaces on one half of the courtroom, opposite the jury box. An off-center bench solves the problem of unused spaces to a large extent, but creates design challenges to maintain the symbolic importance of the judge. Some judges prefer a corner bench. A corner bench makes it very difficult to portray the symbolic importance of the law. However, it reduces the amount of head turning (owing to focus shift) required between the two main foci in the courtroom: the bench and the jury box. Some judges feel that it provides a more casual relationship between the people in the well, which they consider as important. Figure 4.6 shows alternative bench locations.

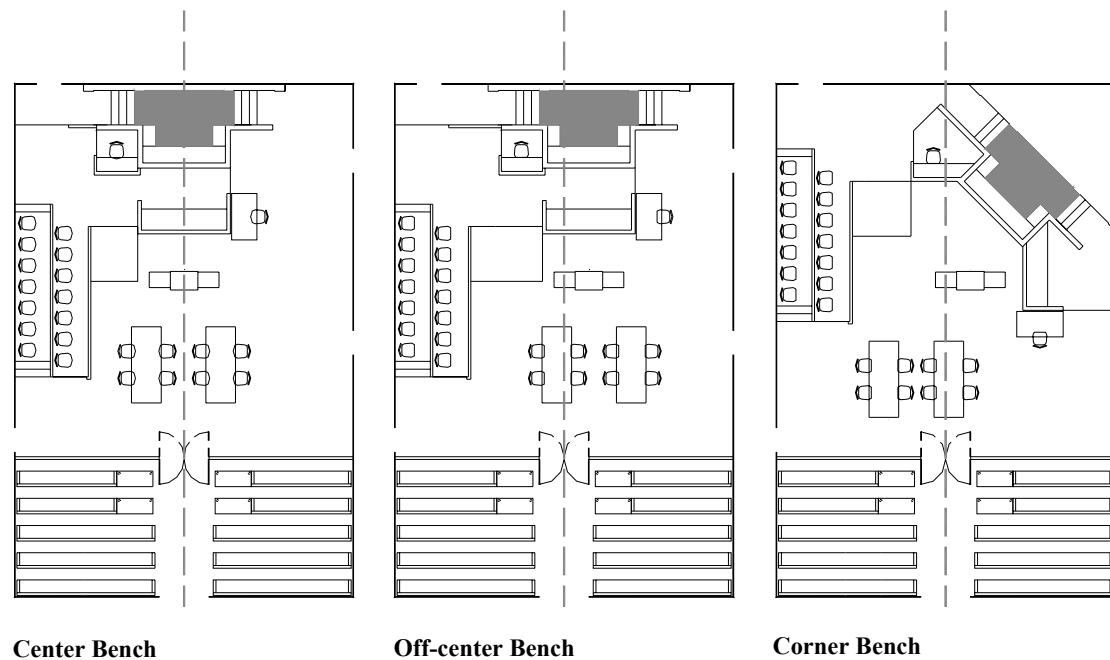


Figure 4.6: Shaded areas showing alternative bench locations in courtrooms.

The witness box, typically, has three possible locations. Those are: on the side of the jury box maintaining axis with the bench (jury box side straight), on the jury box side but slightly turned towards the center of the well (jury box side curved), and opposite the jury box (figure 4.7). The different locations change the view of the witness from other locations in the courtroom. Jury box side straight enables a frontal view to the jurors but a profile view to the judge. Jury box side curved provides a three-quarter frontal view to both the judge and the jurors. Opposite jury box provides a frontal view to the jurors (with minimal head turning) and a profile view to the judge. Viewpoint may be a significant factor, but this has not been well studied in contemporary society, although some literature about its importance in the past is available (Taylor, 1993). Further, the

opposite jury box location creates some constraints to the width of the well since beyond a certain distance facial expressions of the witness may lose clarity when viewed from the jury box. While this location makes some use of the unused portion of the well, it may not suit the lawyers who have to turn their backs to the jurors when examining the witness.

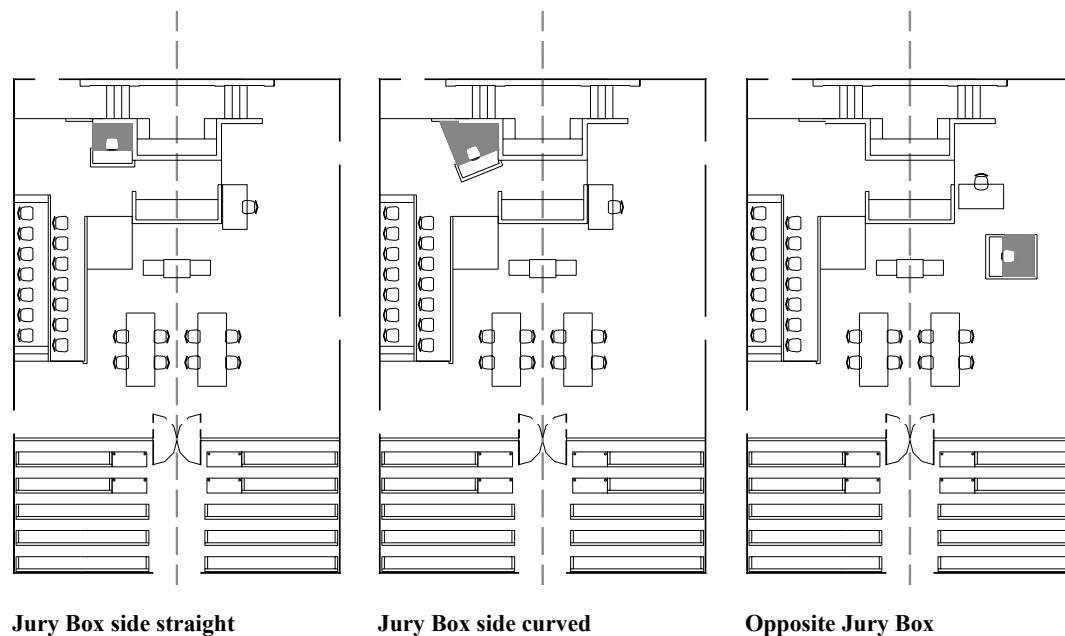


Figure 4.7: Shaded areas showing alternative witness box locations in courtrooms.

The jury box design affects courtroom operations in many ways. The capacity of the jury box influences its size and number of tiers. Jury box capacity changes depending on jurisdiction and courtroom type. The number of tiers in a jury box affects the width, as discussed earlier. The number of tiers also influences the performance of the attorneys. Moving while addressing the courtroom is an integral part of many attorneys' work strategy. Their body language supplements their verbal arguments. Their movement is so

crucial to their operation that the number of tiers in the jury box, according to some attorneys, also affects significantly the effectiveness of their presentation. Lesser number of tiers in the jury box provides larger maneuvering spaces for attorneys to operate. This also requires lesser well width. More tiers, while increasing the intimacy between the attorney and the jury (something desirable from the attorney's viewpoint) restricts their movement (by making the jury box narrower), affecting the way they relate to their workspace. Another design issue related to the jury box is the level of the first row of the jury box. From a symbolic viewpoint a level higher than the well floor is considered essential, where the jurors are at a higher level than the litigants. However, raising the level also influences provisions for handicap access. As earlier indicated, providing access through ramps increases the area of the well significantly.

4.5.4 The auditory environment

Just as courtroom elements influence the size and shape parameters and vice-versa, decisions in the physical domain influence environmental variables such as acoustics too. Acoustics are extremely important owing to the critical nature of verbal communications in courtrooms. That is reflected in the task descriptions, where the ability to hear clearly or privacy of speech (outlined previously) is important to every user.

The size of the courtroom (in addition to other factors) affects this aspect of courtroom function. Reporters and attorneys report how easy it is to hear others speak in smaller courtrooms. In fact, smaller courtrooms can do without electronic sound reinforcement

systems as has been observed in site visits. As wells and courtrooms increase in size, the audibility of speech begins to get affected. Most modern courtrooms, as a result, come with microphones in most of the key areas of the well. However, microphone placements, as observed during site visits and confirmed through discussions, do not change the way actors in the courtrooms behave. Thus the attorneys, while addressing the courtroom (judge, jury, witness) is not restricted by the placement of the lectern or the attorney tables, where microphones are available. They move between the lectern, their table, the witness stand and the jury rail in a continuous fashion, frequently turning their backs to the people in the well for whom every word they speak matters (for instance, the reporter). Once outside the sensitive zone of the microphone settings, the attorneys, theoretically, are in free field conditions, where the audibility of their speech depends solely on the power of speech output, the direction of speech, and the ability of the courtroom enclosure to reflect/diffuse the speech. Owing to low background noise level in most courtrooms, generally, the attorneys rarely raise their voice levels for improving audibility. As the distance between the source of speech and the nearest reflector increases, the level of sound reaching the key elements within the well reduces, affecting the audibility of speech. Reporters, whose tasks involve recording the proceedings verbatim, frequently complain about problems in clearly hearing spoken words in the courtroom. The difficulty increases when persons addressing the courtroom have accent. Jury boxes and galleries have similar problems. Acoustics in galleries are especially important during the jury selection process, where the juror pool responds to questions posed by attorneys and judges. Attorneys' behaviors, however, constitute the most significant acoustical problems in the courtrooms. Using advanced electronics have been

tried without success. Attorneys have been provided with cordless microphones, for instance, to overcome the problem associated with their mobility. This has led to problems where attorneys forget to switch it off during their private conversations. Allocating separate frequencies to each courtroom in large courthouses has also been a major problem with cordless microphone setups that use radio frequencies. While a possible solution to this might be restricting attorneys to the lectern (and this has been done in some federal courthouses), such restrictions might negatively impact their tasks and effectiveness, as addressed in the section on jury box design.

Similarly, the number of jury tiers, and the gallery capacity also influence the acoustical environment in the courtroom. More tiers in the jury box entail wider well dimensions and larger wells, thereby affecting the audibility in the courtroom. The gallery poses a similar issue. For symbolic reasons or extreme scenarios courtrooms are provided with gallery seating capacity more than what is required for normal occasions. Other than in high profile cases, galleries in jury courtrooms remain sparsely populated. The jury selection phase necessitates large seating capacities in galleries, which otherwise remain underutilized during the hearing process. Larger gallery areas increase the volume of the courtroom and possibly affect the speech audibility problem addressed earlier, although this may satisfy the symbolic function to a greater degree. Larger gallery areas also increase the distance between the judge and some of the jurors in the gallery making it increasingly difficult for the judge to read juror's faces. In addition, most gallery seats are made of wood, thus altering the reverberation time in the courtroom significantly depending on the size of gallery audience.

4.5.5 The visual environment

A related issue is of sightlines. As most acoustical literature suggests, good acoustics and good lines of sight generally go together. There are a number of factors in a courtroom that affect sightlines between elements. Those include the millworks and elevations of different elements, the location of the elements, and position, type and level of integration of courtroom technology elements. A good visual environment also includes good lighting conditions, besides good sightlines.

Courtroom lighting affects performance in many ways. Besides influencing the ability to read and write, a key area of influence is in clarity of observation. While large courtroom dimensions increase the distance between parties reducing the clarity of observation, courtroom lighting, too, significantly influences perceptions of facial expressions even from short distances. An example is the courtroom in the Corpus Christi federal courthouse. There, readings of illuminance on work planes confirm to the recommendations in the United States Court Design Guide (AOUSC, 1998). However, facial expressions are difficult to read. A possible reason could be the contrast between vertical and horizontal illumination that begins to cast shadows on faces, rendering degrees of artificiality to the interior visual environment. Further, many new courtrooms are designed to receive natural light, and many courtrooms are designed to provide much higher illumination through natural and artificial lighting than what USCDG recommends. Placement of high luminance light sources and windows in the courtroom

can produce glare sources that could potentially make visual reading of facial expressions a difficult task.

Some of the lighting and acoustical parameters, that seem to affect courtroom tasks, were covered above, which were identified through personal observations. There are, potentially, many other aspects of the lighting and auditory environment that could affect task performance, in general. A review of the literature in those areas highlights some of the key variables, which are discussed in the subsequent sections.

4.6 Summary

Four factors are crucial to courtroom performance:

- The ability to see clearly and perform visual tasks.
- The ability to hear clearly when spoken to by other people, and the ability to discuss issues with others without being overheard, in many circumstances.
- The ability to perform each phase of the proceeding without undue disturbance or obstructions - smoothness of task flow.
- Ensure safety and security of all people, proceedings/function, and objects (such as evidence) throughout the court proceedings.

Parameters in the as-built environment that are hypothesized to influence courtroom performance includes the size and shape of courtrooms and courtroom elements, locations of courtroom elements, factors in the visual environment, and factors in the auditory environment.

Chapter 5

Factors in the Visual and Auditory Environments

The exploratory study described in chapter 4 suggested that several physical parameters of courtrooms, along with visual and auditory factors influence courtroom performance. Visual and auditory factors hypothesized to influence performance are well documented in EB as well as engineering literature. This chapter outlines the visual and auditory factors highlighted in literature. Based on the exploratory study in chapter 4 and the literature survey in this chapter, the scope of this study is defined at the end. This chapter includes:

5.1 Factors in the visual environment affecting performance

5.1.1 Introduction

5.1.2 Key variables

5.1.3 Illuminance

5.1.4 Light direction and shadows

5.1.5 Luminance

5.1.6 Glare

5.1.7 Spectral power distribution

5.1.8 Visual contact with exterior

5.1.9 Viewing distance

5.1.10 Time

5.1.11 Age

- 5.1.12 Thermal conditions
- 5.1.13 Choice and personal control
- 5.1.14 Factors important to screen-based tasks
- 5.2 Factors in the auditory environment affecting performance
 - 5.2.1 Introduction
 - 5.2.2 Reverberation time
 - 5.2.3 Noise level
 - 5.2.4 Signal-to-noise ratio
 - 5.2.5 Distance
 - 5.2.6 Visual cue
 - 5.2.7 Binaural versus monaural hearing
 - 5.2.8 Echo and other long delayed reflections
 - 5.2.9 Vibration
 - 5.2.10 Age/ hearing ability of listener
 - 5.2.11 Gender
- 5.3 Interaction studies
- 5.4 Scope of the study
- 5.5 Summary

5.1 Factors in the visual environment affecting performance

5.1.1 Introduction

This section outlines some of the factors that appear to (or are hypothesized to) affect performance in the visual domain. Courtrooms, per se, have not been the subject matter of investigation in the past, and such studies, if any, are not widely available in published literature. Most studies investigating association between variables in the visual domain and aspects of human behavior have been reported in engineering and psychology literature. Many involve findings from experimental (contrived) settings. Further, a large number of engineering studies involve the use of contrived tasks that may or may not have relevance to actual tasks performed in real life settings. The setting is also another aspect deserving attention. Many early engineering studies were focused on industrial (assembly-line like or factory type) settings. Such early works also involved a considerable focus on military applications, as in fighter plane cockpits. In most of those studies, at most two variables were allowed to vary while the rest were controlled. Published research works in psychology and cognitive sciences also involve experimental settings with limited number of free variables. Hedge (2000) has summarized the developments related to research on work environment. He points out that the beginning of the 1900s witnessed research on environmental concerns including thermal conditions, ventilation, odor, and lighting in factory and early office environments. The 1920s studies on work environment widened to include harsh environments, including heat and cold stress, noisy settings, effect of altitude and similar topics. Changes in building technology

and office design during the 1960s and 1970s (and probably the energy crisis of the 1970s and subsequent changes in building envelop technology) led researchers to focus on appropriate thermal, air quality, and lighting conditions in work and classroom settings. Revolutions in computing technology during the 1980s and beyond, which led to increased computerization of work settings, resulted in new lines of inquiry dealing with comfort, health, and performance issues. As the characteristics of the work environment move further away from the work settings of the previous decades, many researchers are resorting back to theories dealing with evolutionary fundamentals to garner a fresh look at man-environment interaction in the new, increasingly changing and unfamiliar work environments.

More recent studies include works that also involve field studies, in an attempt to understand the environment-behavior relationships in more naturalistic settings such as offices and classrooms. These and the older studies provide some grounds to isolate important physical variables that could possibly affect performance in courtroom settings. While the experimental studies offer some robust findings on isolated variables, some field studies focusing on office settings and classrooms deal with tasks close to those performed in courtrooms. Courtrooms, from a broader perspective, have some similarities to classrooms. Two important aspects – speech and visibility – are as important in classrooms as in courtrooms. Similarly, courtrooms have something in common with workplaces. It is a place where a wide variety of stakeholders in the judicial process congregate to perform certain official functions. Thus, studies on schools and office settings could provide some valuable insight on variables of importance in courtroom

settings. One of the areas where courtrooms differ from office settings is in the fact that most regular users of courtrooms do have a separate workstation outside the courtroom, and congregate in the courtroom for a limited duration. Further, the significance and importance of courtroom tasks are of such high intensity that it could be compared to a fighter plane cockpit, where arousal levels are high, and consequences of actions are non-trivial. Uniqueness of courtrooms as work settings notwithstanding, both engineering and psychology literatures provide a fertile knowledge base to draw on, for investigating environment-behavior relationships in courtroom settings.

The attempt here is not to provide a comprehensive review of all literature published on lighting and acoustics. Rather, the primary attempt is to obtain an understanding of all factors that has been shown to or could affect performance in courtrooms. Recently published textbooks and review articles provide a good source of information towards this objective (such as Veitch & McColl, 2001 and Dillon & Emurian 1996). The chapters and review articles cited in the subsequent paragraphs also synthesize earlier works conducted since early 1990s. In addition, the sections below include a review of pertinent journal publications over the past 15 years.

5.1.2 Key variables

Ambient lighting conditions and its impact on performance, affect, satisfaction, and preference have been researched more as compared to ambient acoustical conditions. One explanation could be that manipulating lighting conditions is relatively easier and less

expensive than changing variables in the acoustical environment. As a result, a host of variables in the visual domain have been researched and hypothesized to influence user behavior. These factors are not restricted to the visual domain; several other biological, physical, social, and psychological factors have been shown to influence performance of visual tasks. Factors not related to ambient lighting that have been investigated and shown to influence user behavior in early controlled laboratory studies include fatigue, noise, sleep loss, incentives, heat, alcohol, sedatives, and time of day (Boff & Lincoln, 1988b). Variables in the luminous environment that have been reported in textbooks include illuminance, background luminance against which task is seen, observer's experience and expectation, and size of detail (Ruck, 1989b), and task luminance and directionality of light (Ruck, 1989a). Veiling reflection and glare are some of the potential disturbing outcomes of directionality of light. Two additional factors are the length of time that is available to study the task, and color (Erhardt, 1996). Most of the laboratory-based studies focused on industrial and military tasks, however, and need certain qualifications before being considered for the types of tasks that are targeted in this thesis. As Ruck (1989b) points out, "although there are many tasks in which fine visual discrimination is a critical component, in the majority of workplaces it is not. The acceptance and application of criteria derived from threshold performance experiments have led to the present tendency of installing very high levels of lighting, i.e. 1000 lux (about 100 FTC) and above. Such high levels are undesirable because of their side effects, e.g. on arousal and discomfort" (p.91).

But how important is the lighting environment in workplace settings, so far as performance is concerned? Crouch & Nimran (1989) developed a descriptive model focused on office workplace settings that was designed to outline and isolate key characteristics that users of such settings feel to be important. They surveyed 174 senior managers from administrative and technical functions and obtained their opinion regarding characteristics of the office surrounding that they believe to facilitate or inhibit performance. The objective was to obtain a comprehensive range of characteristics from the users, and gain an understanding of their relative importance. Facilitators of performance as identified by managers included lighting (natural light and adequate light), and visual outlook (window view). Inhibitors of performance included lighting (lack of natural light, inadequate light), and poor view. Lighting conditions, thus, appear to be a symmetrical factor that both facilitates and inhibits performance depending on designed conditions. This is further reinforced by Gifford (1997), who provides a list of variables in work settings that are influential on task performance including light and color, sound, temperature, air, and space. Discussing specifically on office settings, he touches upon many factors, including some of the ones mentioned above. He contends that within the range of prevalent office lighting, task performance increases with increase in light. Optimal level, however, depend on task type and complexity (level of visual demand). He points out glare as a factor that impedes performance, as well as the direction of light (direct vs indirect lighting). He asserts that increased light leads to increased arousal, and improvement in cognitive performance. He also argues that spectral composition of light has little impact on performance. Nevertheless, there seem to be an impact on preference. Presence of windows (natural light and view), gender, and

age are some of the other factors pointed out by him as important for visual tasks in office settings. The variables briefly referred to above, and additional ones, are discussed separately in the subsequent sections. The discussion starts with the most fundamental variable targeted in studies on the luminous environment – illuminance.

5.1.3 Illuminance

Illuminance is a measurement of the amount of luminous flux incident on a surface per unit area. Luminous flux is the range of radiant energy radiated from a light source that stimulates the visual perception. Available literature focus on three forms of association between illuminance and human behavior:

- Influence of illuminance level on task performance.
- Impact of light quality and quantity on performance.
- Indirect effects of illuminance on performance, such as through stress or affect.

It is conventionally accepted that higher illuminance level results in better visual task performance. Illuminance is one of the first variables to be targeted in engineering research, particularly for industrial and military applications where task complexity is high and lighting levels provided were low compared to today's standards. Earlier studies focused on the effect of illuminance levels on visual acuity (sharpness of vision) in contrived settings, while some more recent studies dealt with task performance in field settings. While the findings from numerous studies generally suggest a positive association between illuminance and task performance, the exact nature of association reported has not been consistent. A meta-analysis of lighting studies reported in 1997

implies that higher illuminance always results in an increase in productivity (Gifford, Hine, & Veitch, 1997). Similarly, in a field study focused on daylight in elementary school settings in three large school districts, the investigators demonstrated a consistent positive association between improved daylight and increased test scores (Heschong, 2002). However, results from other studies support the law of diminishing returns. As illuminance is increased, performance improves until a saturation point is reached, beyond which illuminance has little impact on performance (Boud, 1973; Ruck, 1989b). Field studies dealing with limited range of illuminance levels in office settings (as opposed to experimental settings) corroborate the assertion that within acceptable range of illuminance, it ceases to be an influential variable (Charness & Dijkstra, 1999). This suggests that other factors play a significant role (and may interact with illuminance) in influencing the performance of visual tasks. Some of those factors are environmental and physiological (elaborated in later sections). Yet others relate to the characteristics of the task performed. Studies on task characteristics suggest that the association between illuminance and performance is moderated by the complexity of task performed. For instance, controlled studies on contrived tasks highlight that lesser size and contrast of details demand higher illuminance, controlling for performance level (Katzev, 1992; Ruck, 1989b). This phenomenon is reflected in the lighting codes where recommended illumination levels vary depending on the complexity of task involved (Rea, 2000).

High illuminance levels could (despite some positive findings above) induce stress and impede performance. Ruck's (1989b) observations that high illuminance levels could lead to negative outcomes is supported by a more recent study published in 2001. Basso

(2001) conducted a study that focused on the stress-inducing facet of illuminance. The study does suggest some association between illuminance and/or spectral power distribution (light quality), and stress.

Lighting quality and illuminance, combined, have been the subject of investigation of numerous studies. Some studies in field as well as experimental settings investigated the influence of quantity and quality of light on performance, affects and other outcome variables. The studies included illuminance levels and light quality (spectral properties) as independent variables. While illuminance has been shown to have significant influence on outcome variables, spectral properties of light have not proved to be as influential (Baron, Rea, & Daniels, 1992). Light quality is further elaborated in a separate section on spectral properties later.

On the whole, literature suggests that illuminance is associated with task performance and preference (subjects show a preference for illuminance around 50 FTC). However, the association is moderated by type and complexity of tasks. Further, illuminance at very low and very high levels could induce stress. Owing to the nature of the studies reported, another aspect of the visual environment (spectral properties) was partially discussed in this section. As will be discussed later, there are no consistent findings about the impact of spectral distribution on user behavior. However, the presence of natural light seems to have a positive association with performance. Details of the citations in this section are elaborated in Appendix IV, section 4.1. Table 5.1 summarizes the citations included in this section.

Table 5.1: Influence of illuminance on human behavior and performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-----------------------------|---|---|--|
| (Boud, 1973) | Illuminance, visual acuity | | Acuity increases rapidly with increase in illuminance up to a level, beyond which increment in illumination result in little improvement. |
| (Boff & Lincoln, 1988a) | Task illuminance, background illuminance, visual acuity, object color | | Visual acuity increases with increase in background illumination, but the relationship is moderated by the color of the object under study vis-à-vis the background. |
| (Ruck, 1989b) | Illuminance, task performance | | Increasing illuminance follows the law of diminishing returns in task performance. |
| (Katzev, 1992; Ruck, 1989b) | Illuminance, size of detail, contrast | | As the size and contrast is reduced, the illuminance level needs to be higher at which it saturates. |
| (Baron et al., 1992) | Illuminance, spectral distribution, task performance, affect | Investigate the impact of illuminance and spectral distribution on performance on a wide range of work-related tasks. | No gender difference on any of the dependent measure. Illuminance had a significant impact on subject's performance on several tasks. Lamp color produced less consistent results. No mediating role of affect was found. |
| (Katzev, 1992) | Illuminance, spectral distribution, task performance, mood | Investigate the impact of illuminance and light color (of energy efficient office lighting systems) on productivity, preferences, and affect. | Relatively modest impact of lamp type on a few tasks. Subjects showed a preference for lighting levels of 45 to 55 FTC. |
| (Gifford et al., 1997) | Illuminance, productivity | Greater illuminance increases productivity. | A linear relationship between the illuminance and productivity. |

Table 5.1 (continued)

| Source | Variables | Hypothesis/ Objective | Conclusions |
|----------------------------------|---|--|---|
| (Charness & Dijkstra, 1999) | Illuminance, task performance, age | Investigate association between ambient lighting level and legibility performance, and to see if the relationship is moderated by age. | Lack of any significant association between ambient illuminance and task performance. No main effect of lamp type. |
| (Basso, 2001) | Illuminance, spectral distribution, skin conductance | Dim and cool-white lighting are more stressful as compared to bright and full-spectrum lighting. | Significant difference between cool-white and full spectrum lighting. Cool-white light was associated with higher stress, especially under low illumination condition. |
| (Heschong, 2002) | Daylight illuminance, test scores | Investigated the association between natural light and performance of school children. | A consistent positive association between increased daylight and improved test scores |
| (Morita, Hirano, & Tokura, 2003) | Illuminance, color temperature, core body temperature | A relationship exists between core body temperature and preference for lighting conditions. | Subjects preferred higher illumination and color temperature during periods of rising core temperature (daytime after waking) and lower illumination and color temperature during periods of falling core temperature (late afternoons and periods before sleeping) |

5.1.4 Light direction and shadows

Facial observation, per se, has not been studied widely. One reported study (Wagenaar & Leiden, 1996) attempted to develop a rule of thumb for optimum distance and illumination in courtroom settings for best results in observing faces. The author

recommended a rule of fifteen – at most 15 meters and at least 15 lux as the limits. A few recent studies focusing on face recognition offer some valuable insight into factors that may influence clear observation of faces. In courtrooms, face recognition is an important necessity for all actors.

In addition to distance, direction of light and cast shadows seem to be important variables. This could be inferred from two recent studies dealing with representation of facial information and recognition of faces (Braje, Kersten, Tarr, & Troje, 1998; Hill & Bruce, 1996). Both studies (elaborated further in Appendix IV, section 4.1.2) dealt with light direction and effect of shadows on recognition of familiar and unfamiliar faces. Using computer simulations of face models, direction of light and presence or absence of shadows was systematically manipulated. The results suggest that change in light direction, viewpoint, and presence of cast shadows significantly affected reaction time and accuracy. Table 5.2 summarizes the studies referred to in this section.

Table 5.2: Influence of light direction and shadows on face recognition.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|----------------------|---|---|---|
| (Hill & Bruce, 1996) | Light direction, observer's viewpoint, models of familiar faces | Edge-based information may be insufficient for face recognition. Objective was to examine the effect of shadows on face perception tasks. | In face matching tasks change in light direction as well as viewpoint significantly affect task accuracy. Matching task accuracy was highest for upright top-lit faces. |
| (Braje et al., 1998) | Light direction, cast shadows, models of unfamiliar faces | To examine the impact of changes in lighting direction and cast shadows on face recognition. | Changes in light direction have a negative impact on face matching accuracy. Cast shadows have negative influence on reaction time, but not sensitivity. |

While the time duration involved in these studies for face matching tasks may not be representative of time available for face recognition in courtroom settings, the fact that shadows and lighting direction could affect face recognition is of importance. This is especially due to the importance attached to minute observation of facial movements and postures in courtrooms – of potential jurors during the jury selection process, of witnesses and defendants during trial, and the judge during all phases of the courtroom proceedings. While most courtrooms have top lighting conditions, differences arise between direct and diffused lighting, additional lighting from windows, and light reflectance from vertical surfaces. The issue of reflectance draws the discussion to the third major variable in the visual environment- luminance and brightness balance.

5.1.5 Luminance

Luminance is a term that expresses luminous flux by unit area of a luminous or reflecting surface (Boud, 1973). From the viewpoint of human-environment interaction studies, luminance is a more meaningful variable (as compared to illuminance), since people live and work in the luminous environment. Illuminance is outside the purview of human perception. Moreover it is the ratio of brightness in the ambient environment that is generally perceived and reacted to by humans. The essence of the distinction is lucidly articulated by Erhardt (2000), who asserts, “the visual system can be thought of as a system that compares light rather than measuring it. At no point does such a system seem to need absolute luminance information...Unlike manmade measuring devices, the

human visual system seems capable of processing multiple variables simultaneously...”

(p.8). Luminance and illuminance are related insofar as luminances of surfaces are the result of the illuminance and reflectance related to the surface. Luminance, however, is a lesser-studied variable of the visual environment, owing to complexities involved in developing standardized protocols for luminance measurements on site. Cost of instruments needed for measuring luminance could also be a prohibiting factor. Probably owing to these factors, most studies on brightness are reported in controlled laboratory settings.

Controlled studies on luminance suggests that increasing mean luminance levels result in an increase in contrast sensitivity, and visual acuity (Boff & Lincoln, 1988a; Ruck, 1989b). Other factors interact with luminance to influence visual performance too, at least in contrived tasks. Such factors include size of detail and time period of exposure. At higher levels of the variables, changes result in incrementally lesser influence on visual performance (Boff & Lincoln, 1988b; Ruck, 1989b). Most of these studies dealt with threshold levels, which may not be the case in field situations. Field studies suggest that people may have preferred range of luminance and brightness balance in work settings, such as task: luminance ratio for the wall facing the task at about 0.55, 0.48 for walls alongside the task, and 0.5-0.8 for the ceiling (Ruck, 1989b), and task brightness preference of 190-890 cd/m² (Hedge, 2000). The citations here are further elaborated in Appendix IV, section 4.1.3, and summarized in table 5.3.

Table 5.3: Influence of luminance on task performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|---|--|--|
| (Boff & Lincoln, 1988a) | Background luminance, visual acuity | | Acuity increases as background or mean luminance level increases |
| (Ruck, 1989b) | Luminance, visual acuity | | Increasing luminance results in greater contrast sensitivity and hence better visual acuity |
| (Ruck, 1989b) | Size of detail, time of exposure, luminance, visual performance | | Equal changes in size, luminance or time, when the levels of these variables are high, produces lesser influence on visual performance as compared to when the levels are low. |
| (Boff & Lincoln, 1988b) | Luminance, time of exposure, reaction time | | Reaction time is inversely related to the duration of exposure, with constant luminance. |
| (Ruck, 1989b) | | | With illuminance for offices recommended at 500-700 lux (about 50-70 FTC), the optimal environmental conditions occur when the task: luminance ratio for the wall facing the task is about 0.55, 0.48 for walls alongside the task, and 0.5-0.8 for the ceiling. |
| (Hedge, 2000) | | Subjects' preference for general and workstation lighting. | Workers prefer task brightness between 190-890 cd/m ² . |

Based on textbooks and published literature, it could be concluded that brightness (or luminance) ratios are an important aspect of the visual environment that influence visual acuity and task performance. Task brightness, brightness of the background, size of detail, and time of exposure appear to be important factors. Time of exposure (discussed later in a separate section), presumably, is not of much concern in a courtroom setting,

and courtroom tasks do not vary much between courtrooms (task characteristics are standardized through regulations). Task and background brightness, however, appear to be pertinent for this study. The brightness ratios between task and other surfaces in a space, in certain conditions and at certain levels, also create a visual problem that is commonly known as glare.

5.1.6 Glare

Glare is a common term used in everyday language, but a considerably more difficult phenomenon to grasp compared to any other factor in the visual environment. Measuring it in field setting is complicated, since most of the theoretical works (models) on glare are extremely difficult, if not impossible, to translate into field protocols. Experiments involving glare have been conducted in highly controlled settings, and most literature on glare have been confined to theoretical models. Reports on their validation in actual settings are not widely published. As Boud (1973) points out, the difficulty in studying glare is in the fact that “over glare, in general, there are few absolutes; what would be intolerable in an office could be exciting in a fairground” (p.13).

Nevertheless, glare is encountered by people in everyday situations, and presumably affects behavior in many ways. Lighting textbooks distinguish between two kinds of glare: disability glare and discomfort glare. Discomfort glare is caused by variations in luminance across the visual field. Disability glare is caused by the intensity of glare sources and reflections of light from high reflectance surfaces (Ruck, 1989b). Normally,

disability glare is rare in interiors. Most interior environments are susceptible to discomfort glare. Boud (1973), among others, highlights the factors that influence glare sensation. Those include luminance (brightness) of surfaces, size of luminous surface at the viewpoint in question (solid angle), and position of glare source in relation to the direction of view. Theoretical models of glare include all of these factors. Boff & Lincoln (1988b), based on previous laboratory studies, report that glare causes a decrease in visibility. The magnitude of decrease in visibility is directly proportional to the intensity (luminance) of the glare source. The angle of the glare source from one's line of sight is also a factor. The impact is most when the glare source is in the line of sight of the subject. The citations in this section are summarized in table 5.4.

Table 5.4: Influence of glare on visual tasks.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|-----------------------------------|-----------------------|---|
| (Ruck, 1989b) | | | Discomfort glare is caused by variation in luminance across the visual field. Disability glare is caused by the intensity of glare source and reflection of light sources from high reflectance surfaces. |
| (Boud, 1973) | Luminance, solid angle, direction | | Factors influencing glare sensation include luminance (brightness) of surfaces, size of luminous surface at the viewpoint in question (solid angle), and position of glare source in relation to the direction of view. |
| (Boff & Lincoln, 1988b) | Luminance, direction | | Glare causes a decrease in visibility. The magnitude of decrease in visibility is directly proportional to the intensity (luminance) of the glare source and angle of the glare source from one's line of sight. |

For field studies like POEs, measurement of glare poses a logistic problem. In courtrooms three factors seem to be intuitively important: the intensity of glare source (windows, high luminance light sources), the size of glare source (light trays, ceiling domes), and the relative position of glare source in the field of view. Discussions on the operationalization of glare are included in chapter 6.

5.1.7 Spectral power distribution

Spectral power distribution is related to color perception. Color perceived by human beings is a function of the spectral power distribution and characteristics of surfaces from which the light is reflected. In essence spectral power distribution is the distribution of light energy in each frequency band of the visible spectrum. While the impact of color on human behavior has been the focus of study for a long period, study of the spectral power distribution mostly originated with the advent of more sophisticated artificial lamp types. Traditional incandescent lamps, and the first generation of fluorescent lamps (used in office settings) vary substantially in their spectral distribution from daylight.

Developments in lamp technology brought more energy efficient lamps in the market, as well as those that were closer to daylight in spectral distribution. The later development drove numerous research endeavors that originated from the evolutionary theory. The theory propounds that evolutionary events lend humans to experience lesser stress (and more comfort) in visual surroundings that resemble daylight in spectral qualities.

Objective measurement of the spectral qualities chiefly depends on two standard measures: the color temperature of light source, and the Color Rendering Index (CRI). Color Temperature of a source of light is obtained by comparing the spectral distribution of the source with that of the radiation from a theoretical perfect black body. CRI provides a comparison between a light source and daylight (or a standard lamp). Most studies on spectral quality of light have focused on the impact of different lamp types and reported color temperature as the variable of interest (a few studies have reported CRI of the lamp types). Study results have been inconsistent in finding any association between spectral qualities of light and performance. Early studies suggested a significant association between spectral qualities and visual acuity (Boff & Lincoln, 1988a). Such studies also hypothesized direct association between spectral distribution and visual tasks arising out of the former's influence on pupil size (Ruck, 1989b). Yet other studies provided evidence on the impact of light quality on psychological and physiological processes (Ruck, 1989a, 1989b), such as comfort mood and preference, which were used as hypothesized mediators in some later studies. In general, full spectrum lighting, in the earlier studies as well as some recent studies, was shown to have positive influence on mood, comfort, achievement, performance, and perception of visual clarity (Hathaway, 1995; Knez, 2001; Vrabel, Bernecker, & Mistrick, 1998). Yet other studies found little evidence in favor of significant associations (Hedge, 2000; Knez & Enmarker, 1998; Knez & Kers, 2000; Veitch, 1997).

However, the general focus on color temperature may have been the problem. As asserted by some (Veitch & McColl, 2001), CRI is more influential in rendering color perceptions

than color temperature. The authors also point out some other flaws in earlier studies that may account for the inconsistent findings. Yet, another possible confounding factor could be the phenomenon of color constancy (Boud, 1973). Similar to size and brightness constancy, the human cognitive apparatus retains color information of objects despite changes in lighting conditions. Moreover, it could be argued that spectral qualities of lighting in offices, and schools are within a reasonable range of variation, and color constancy may be a reason for the lack of consistent behavioral response. See Appendix IV, section 4.1.4, for elaborate descriptions of the studies cited in this section. Table 5.5 summarizes the citations discussed in this section.

Table 5.5: Spectral qualities of light as an influential factor in visual tasks.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|---|--------------------------|---|
| (Boff & Lincoln, 1988a) | Spectral distribution, visual acuity | | Visual acuity is best in greenish light, and reduces with shorter or longer wavelengths. |
| (Ruck, 1989b) | Spectral distribution, pupil size | | Controlling for the light intensity, spectral distribution affects pupil size, and the size of pupil influences the ability to resolve fine details as well as perceive the depth of a field. |
| (Ruck, 1989b) | Spectral distribution, non-visual processes | | Mood, emotional state, muscular activity, breathing, pulse rate and blood pressure are some of the areas believed to be influenced by light color. |
| (Ruck, 1989b) | Spectral distribution, human comfort | | Artificial lights closer in quality to natural light, as compared to conventional fluorescent lights, leads to subjects experiencing more relaxation and eye comfort. |

Table 5.5 (continued)

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|---|---|---|
| (Ruck, 1989a) | Spectral distribution, human comfort | | Light sources that are close in spectral distribution to daylight are regarded by subjects as less discomfoting as compared to subjects working under standard (white) fluorescent fixtures. |
| (Hathaway, 1995) | Lamp type, achievement rate | Investigate non-visual effects of different types of classroom lighting. | Full spectrum fluorescent lighting was associated with more rapid progress in achievement. |
| (Veitch, 1997) | Lamp type, information, performance, mood | Investigate whether ones belief about the full spectrum lighting explains the variance between this and other lamp types. | Neither the fluorescent lamp types, nor the information provided about the lamps had any impact on mood or performance. |
| (Knez & Enmarker, 1998) | Lamp type, performance, mood | Mood and gender act as mediators between lamp types and performance. | No effect of lamp types on cognitive performance. Significant association between lamp types and mood, with an interaction effect with gender. |
| (Knez & Kers, 2000) | Lamp type, gender, age, mood | Lamp types constitute an affective source that is moderated by gender, age or both. | Lamp type had an influence on participant's mood, but only the negative mood. Association with mood was moderated by age, but not gender. Younger participants performed better than older participants in cognitive tasks. |
| (Hedge, 2000) | Lamp type, learning, health, attitude | Investigate the association between lamp types, and learning, health and attitude of children in grade 4 to 6. | No significant findings on health or learning measures. There was a significant difference on comfort ratings. |

Table 5.5 (continued)

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|---|---|--|
| (Knez, 2001) | Lamp type, mood, cognitive performance | Investigate impact of lamp type on mood and cognitive performance. | For short-term recall tasks warm-white lamp was found better, so as in problem solving. Gender acted as moderator in long-term memory tasks. |
| (Vrabel et al., 1998) | Lamp type, perception of visual clarity | Investigate perception of visual clarity under different light sources. | Significant difference arising out of different lamp types. Higher CRI associated with better clarity. |
| (Veitch & McColl, 2001) | | Investigate the reasons for inconsistent results in earlier studies. | Several deficiencies that influence validity of earlier research findings. |

To summarize, in color perception and judgment of spaces, the CRI was found to be a better predictor as compared to lamp type. In cognitive tasks, field studies as well as laboratory experiments have failed to show any systematic effect of performance in children as well as adults. While color has an intuitive appeal as a significant factor affecting user behavior, other than mood, little evidence is available in support of its association with performance. Discussing color, Boud (1973) distinguishes, broadly, between light sources providing a natural effect including a blue sky, a cloudy day, direct sunlight, some fluorescent lamps, incandescent lamps, candles...and sources that produce some sort of distortion (an unnatural effect), including many discharge lamps and some fluorescent tubes, and the sky under some stormy conditions. Possibly, Boud's broader categorization of natural and unnatural effects (or the presence or absence of daylight) could be a measure with greater significant outcomes as compared to CRI and color temperature.

5.1.8 Visual contact with exterior

Beside daylight in interior spaces, the view afforded through fenestrations also seem to be an important aspect of the visual environment. Crouch & Nimran's (1989) study on office settings (discussed earlier) gave some indication regarding the perceived importance of the presence and quality of view from interior spaces. In addition to the changes in spectral quality of the light in interior spaces, some experts believe that contact with exterior enables occupants to remain connected with the diurnal rhythm of nature that influences the biological clock in human beings (Ruck, 1989b), which is argued to influence performance. Ruck reports two works where the acceptability of window sizes has been studied using models of open plan offices. It was found that window area of less than 15% is generally considered disagreeable. More than 30% window area leads to report of complete satisfaction. In a similar experiment the investigators found that a window/wall ratio of 25% is the minimum acceptable for 50% of the subjects. At 32% the acceptance rose to 85% of observers.

Ternoey (2001) asserts that view may be more important than daylight. He argues that human performance has been shown to improve without daylight, and it was the transparency of the interior spaces to the exterior (thus the view) that provides more explanation for improvement in performance. He claims that the benefits increase with the degree of transparency until a point where the views afforded through transparency

begins to be distracting, or affect visual or thermal comfort conditions. The discussions above are summarized in Table 5.6.

Table 5.6: Influence of exterior view on performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|---|---|---|
| (Crouch & Nimran, 1989) | Performance, exterior view | Outline and isolate key characteristics that users of office settings feel to be important. | Exterior view is a facilitator of office performance. Poor view is an inhibitor. |
| (Ruck, 1989b) | Contact with exterior, physiological processes, performance | | Contact with exterior influences physiological processes, which influences performance. |
| (Ruck, 1989b) | Window area, acceptability | Investigate acceptability of window sizes in open plan offices. | Less than 15% is generally considered disagreeable. More than 30% window area leads to report of complete satisfaction. |
| (Ternoey, 2001) | Transparency, performance | View may be more important than daylight. | Benefits increase with the degree of transparency until a point where the views afforded through transparency begins to be distracting. |

While exterior visual contact is not studied as much as other variables, it appears to be an important factor contributing to performance. However, the distractions caused by transparency might turn out to be a problem in courtroom settings.

5.1.9 Viewing distance

Viewing distance is yet another variable studies on which are not widely published. The factor could be important in three situations. It could affect the size of details (already covered in the section on illuminance). It could affect performance dealing with screen-based equipments. And it could affect performance in cases where the task includes observing faces and facial expression as in courtroom settings.

Most early studies have focused on contrived tasks or tasks related to work in industrial and military settings. Boff & Lincoln (1988a) report that increase in viewing distance improves visual acuity as well as stereo acuity (ability to perceive depth) up to a limit. Beyond this limit acuity declines. Discussing about distance for certain tasks in laboratory conditions, they report that viewing distance of 0.5 to 1 meters results in best visual acuity. Target positions beyond 1 m, and lesser than 0.5 m, result in decline in acuity. They further report that viewing distance is more crucial as a factor at low luminance levels, as compared to high luminance levels. As suggested earlier, these findings are less applicable to typical courtroom tasks. One recent study attempted developing rules of thumb for courtrooms, mentioned earlier (Wagenaar and Leiden, 1996). Ruck (1989a) briefly touched upon the importance of viewing distance for works involving screen-based instruments. Studies involving screen-based instruments are discussed later. The literatures cited here are summarized in table 5.7.

Table 5.7: Influence of viewing distance on task performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|---------------------------|--------------------------------------|-----------------------|--|
| (Boff & Lincoln, 1988a) | Viewing distance, visual acuity | | Increase in viewing distance improves visual acuity as well as stereo acuity up to a limit. Beyond this limit acuity declines. |
| (Wagenaar & Leiden, 1996) | Viewing distance, facial observation | | At most 15 meters and at least 15 lux are the limits for effective facial observations in courtrooms. |

Viewing distance in courtrooms is an important variable in at least two conditions. First, when the monitors/screens are fixed to the desktop or millwork thus reducing the possibility of adjustment by individual users, and second, when the task involves observation of faces.

5.1.10 Time

A factor less important to courtroom tasks is the time available to view details. Time, however, has been reported in earlier studies to influence task performance. Once again, the findings are more applicable to industrial and military settings. Boff & Lincoln (1988a) report that for static targets, exposure time up to nearly 300 m sec significantly influences visual acuity. The positive relationship holds true for another 300 m sec, although the association is weaker. In another volume of the compendium (Boff & Lincoln, 1988b) they underscore an important association between luminance and time as they relate to reaction time, in laboratory experiments. Studies suggest that reaction time is inversely related to the duration of flash (or exposure of the object). This relationship,

however, holds true up to about 10 m sec, beyond which the duration of exposure (or flash) becomes insignificant. Keeping time constant, as luminance increases, reaction time decreases. Ruck (1989b) cites previous research about the interaction between visual performance involving printed words and gratings, and size, time and luminance. Equal changes in size, luminance or time, when the levels of these variables are high, produce lesser influence on visual performance as compared to when the levels are low. However, as suggested earlier, time appears to be an important variable, but not in courtroom settings. This is more so since few tasks in courtrooms involve time constraints as low as 300 m sec. The discussions here are summarized in table 5.8.

Table 5.8: Influence of viewing time on task performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|------------------------------------|-----------------------|---|
| (Boff & Lincoln, 1988a) | Exposure time, visual acuity | | For static targets, exposure time up to nearly 300 m sec significantly influences visual acuity. |
| (Boff & Lincoln, 1988b) | Exposure time, visual acuity | | Reaction time is inversely related to the duration of exposure. This relationship holds true up to about 10 m sec, beyond which the duration of exposure becomes insignificant. |
| (Ruck, 1989b) | Size, time, luminance, performance | | Equal changes in size, luminance or time, when the levels of these variables are high, produce lesser influence on visual performance as compared to when the levels are low |

5.1.11 Age

Age has been discussed earlier with reference to its role as a moderator in the association between other variables. User's age, owing to changes in human physiology, results as a significant variable affecting performance. Boff & Lincoln's (1988a) compendium includes some reports about the influence of age. They report, for instance, that in healthy subjects, visual performance (as measured by standard acuity and contrast sensitivity) declines with age. Further, the aging process seems to affect visual performance after the age of 40 and declines progressively through the rest of the life span. Ruck (1989a), discussing productivity in workplace, outlines some key variable that appears to influence performance, including the age of the occupant, workload, motivation and temperature. The discussions here are summarized in table 5.9.

Table 5.9: Influence of age on task performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|-----------------------|-----------------------|--|
| (Boff & Lincoln, 1988a) | Age, task performance | | In healthy subjects, visual performance (as measured by standard acuity and contrast sensitivity) declines with age. |
| (Ruck, 1989a) | Age, performance | | Age of the occupant, workload, motivation and temperature influence productivity in workplace. |

5.1.12 Thermal conditions

Thermal conditions, and more specifically temperature, humidity, and ventilation, have been the focus of numerous studies, and warrant a separate discussion. Indoor environments in courtrooms are generally, however, controlled within limited ranges, and may not be influential in courtroom task performance. Further, as discussed later, thermal conditions are shown to influence performance only in extreme conditions. This variable, hence, is touched upon briefly in discussions on the visual and auditory environments. Some of the studies involving multiple variables (light, sound, heat, etc.) are addressed separately.

Influence of temperature on visual tasks, in earlier studies, shows an association between the variables in extreme conditions. Boff & Lincoln (1988b) report two factors related to thermal conditions: 1) the temperature, 2) duration of exposure. It has been shown that an increase in temperature or duration of exposure increases the likelihood of impaired task performance. For tasks with higher cognitive demand (e.g.: tracking, vigilance, complex tasks), the temperature is more influential as compared to duration of exposure. The authors report slightly different result in cold environments (as opposed to heat). Cold environment (but within the lower limit of the human comfort range), as found in laboratory studies, improves performance in some type of tasks. Table 5.10 summarizes the citations here.

Table 5.10: Influence of thermal condition on task performance.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-------------------------|------------------------------------|-----------------------|---|
| (Boff & Lincoln, 1988b) | Temperature, exposure, performance | | For tasks with higher cognitive demand, temperature is more influential as compared to duration of exposure. |
| (Boff & Lincoln, 1988b) | | | Cold environment (but within the lower limit of the human comfort range), improves performance in some types of task. |

5.1.13 Choice and personal control

For some time EB theorists have propounded user choice as a variable influencing user behavior. Studies on office settings offer inconsistent results in this area as reported by Gifford (1997) and Veitch & Gifford (1996). User choice and personal control, as a variable, is not elaborated further.

5.1.14 Factors important to screen-based tasks

Factors influencing screen/VDU-based (visual display unit) tasks have been published extensively in journal sources. As with the other variables, the attempt here is to identify and outline key variables of importance. To that end all such factors have been included in one subsection (for brevity). Dillon & Emurian (1996), in a review article, outlined a range of variables important for screen-based tasks. The authors surveyed human factor literature related to visual fatigue resulting from use of VDU's. The key variables

identified by the authors include viewing distance, color of VDU character and background, user demographics, duration of VDU use, and glare and physical feature of VDU (see Appendix IV, section 4.1.5 for more details on this section). Boff & Lincoln's (1988b) compendium outlines factors including display screen symbol luminance, display resolution, symbol size, viewing angle, vertical resolution, CRT scan line orientation, CRT symbol size and resolution, CRT symbol size and stroke width, CRT symbol spacing, display element size. One confounding factor, however, associated with studies on screen luminance is pointed out by Duffy & Chan (2002). The fact that VDU luminance decreases over time (although the magnitude of decrement is not commonly agreed upon by the scientific community) creates some reliability problems in experimental as well as field studies. Two variables of pertinence to this study discussed in literature— flicker and viewing distance - are outlined below.

Flicker is caused owing to the refreshing rate of Cathode Ray Tube based screens (Ruck, 1989b). Studies have suggested that flicker is associated with eye-strain, visual discomfort and stress, which in turn influence task performance (Kuller & Laike, 1998; Ruck, 1989a). Kuller & Laike's (1998) study, however, found that the subjects perceived all lighting conditions as low in flicker. Also, no main effects were found for visual comfort, head ache, and feeling of fatigue, or on task performance. The findings supports Boff & Lincoln's (1988b) assertion that the presence of flicker may have been overstated in the large volume of studies. Phosphors in CRT, according to the compendium editors may result in flickers being less prevalent than as predicted in laboratory studies.

As opposed to flicker, screen position may be a factor influencing performance, especially for fixed screen positions. Numerous ergonomics studies have investigated the influence of viewing distance, posture, and angle of vision on stress and eye strain (Aaras, Fostervold, Ro, Thoresen, & Larsen, 1997; Jaschinski, Heuer, & Kylian, 1998, 1999; Liao & Drury, 2000). Results suggest that screen position relative to the user is a significant factor in the workplace (see table 5.11 for summary of the literature discussed in this section). The studies are further elaborated in Appendix IV, section 4.1.5.

Table 5.11: Influential variables in screen based tasks.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|---------------------------|--|--|---|
| (Ruck, 1989a) | Screen flicker, eye strain | | 40% of people working on screens would consider a flicker frequency below 60 Hz as uncomfortable. Users of screen based instruments find fluorescent lighting less than 69 Hz as stressful. |
| (Kuller & Laike, 1998) | Flicker rate, visual discomfort, stress, fatigue, task performance | Flicker from fluorescent lamps are associated with visual discomfort and stress. | Both conditions were perceived as low in flicker content. No main effects for visual comfort, head ache, and feeling of fatigue, or task performance. |
| (Aaras et al., 1997) | Posture, angle of vision | Compare postural loads during VDU tasks. | The least stressful condition involved sitting work with support for forearm. Angle of vision not significant. |
| (Jaschinski et al., 1998) | Eye level, viewing distance, angle of vision, table height | Find the most comfortable working position. | High screens result in greater eyestrain as compared to low screens. Subjects showed a preference for a viewing distance between 60 and 100 cm, and a vertical inclination of 16 deg. |

Table 5.11 (continued)

| Source | Variables | Hypothesis/ Objective | Conclusions |
|---------------------------|--|---|--|
| (Jaschinski et al., 1999) | Vireing distance, strain | Find the most comfortable working position. | Screens at about 66 cm induced more reported strain than screens at about 98 cm. |
| (Liao & Drury, 2000) | Key board height, work duration, joint angle, postural shift, musculoskeletal discomfort, fatigue, performance | To demonstrate the interactions between workplace, work duration, discomfort, working posture and performance | Medium keyboard height was associated with the lowest discomfort |

To conclude, several factors have been consistently shown to influence visual tasks, including illuminance, light direction, luminance, glare, visual contact with exterior, viewing distance, time period of exposure, age, thermal conditions, and screen position. Findings from studies on some other hypothesized variables have not been consistent, including spectral power distribution and screen flicker.

5.2 Factors in the auditory environment affecting performance

5.2.1 Introduction

Similar to studies on lighting, a large number of earlier studies on the acoustical environment focused on industrial or military applications. Research on industrial settings were more concerned with health impact of high sound level, where as the military ones were looking for factors that affect sound signal detection and similar

topics. Later publications provide some insight into more common settings such as schools and offices, and the association between ambient sound and user health, performance, mood, and preference. While courtroom settings may prove to be different from offices and classrooms in many respects, published literature, nevertheless, help outline the important factors in the auditory environment that might affect courtroom performance.

Commenting on the factors that influence one's ability to detect sound Boff and Lincoln (1988a) outline several factors, including medium of sound transmission, frequency, free field versus ear phone presentation, binaural versus monaural listening, signal duration, band width of multi tone complexes, masking, age, and noise exposure. In a separate volume (Boff & Lincoln, 1988b) the authors cite works that offer some empirical knowledge about factors affecting intelligibility of sound. Those include signal-to-noise ratio, interaural differences, frequency, type of masking noise, voice, number of voices in distracter, message content, message redundancy, location of sound source, peak clipping, vocal effort, visual cues, earplug use, listener's age. They also provide some non-aural factors that might impede auditory task performance (based on experiments in laboratory settings) including fatigue, noise, sleep loss, incentives, heat, alcohol, sedatives, and time of day. Not all factors highlighted above may be pertinent in work settings. From a task performance viewpoint, in field situations, the key requirement is in being able to converse or work without distractions, as pointed out by Crouch and Nimran (1989), who found that privacy and absence of distractions are some of the factors found to be important by office managers. Similarly, Gifford (1997) cites a survey

of 1000 office workers who expressed that one of the most important factors affecting them is the opportunity to concentrate without noise and disturbances. Further, job satisfaction had an inverse relationship with noise in a reported survey of 58 sites. Field and experimental studies on office and school settings provide some information on key variables of interest that might also be considered important in courtroom settings. Lawrence (1989a), discussing about task performance in the acoustic environment, highlights two critical area of design. One is an acceptable level of noise. The other is the reverberation time in the space.

5.2.2 Reverberation time

Reverberation is the persistence of sound in a space after the source has stopped. It modifies the original sound source, and thus either enhances or interferes with the sound reaching a listener (Brooks, 2003), thus interfering with task performance in some situations. Reverberation time (RT) in a space is conventionally measured as the time it takes for a sound signal to reduce in pressure level by 60 dB. The desirable level of reverberation time depends on the function of the space. Recommended values are provided in most acoustical design reference books (Tao & Janis, 1997). For a room where speech is the primary task (such as courtrooms), reverberation time affects the clarity of the incoming speech.

Studies on the effect of reverberation on auditory tasks have also, generally, included the interaction effect of noise levels. Such studies have focused on the influence of acoustical

factors on speech intelligibility and learning performance. Findings suggest that the combined effect of reverberation time and noise is more than the individual effects of the variables on intelligibility of speech (Payton, Uchanski, & Braida, 1994). Higher RT, along with noise, results in lesser intelligibility. Also, the two factors interact in a significant ways in impeding academic achievement by influencing speech recognition and learning (Picard & Bradley, 2001). While noise may conventionally be regarded as more detrimental than RT, beyond a certain range the latter could result in reduced ability to comprehend high-frequency consonant and acoustical smearing of words (Towne & Anderson, 1997). Table 5.12 provides a summary of the discussions above. Appendix IV, section 4.2.1 includes elaborations on the cited literature.

Table 5.12: Influence of reverberation time on auditory tasks.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|--------------------------|---|---|--|
| (Payton et al., 1994) | Reverberation time, noise level, speech intelligibility | To study the relationship between speaking styles, acoustical characteristics of settings, and listening abilities. | Combined effect of reverberation and noise was more than the individual effects. A significant interaction between noise and reverberation. |
| (Picard & Bradley, 2001) | Reverberation time, noise, speech recognition | Acoustical impediments to learning | Interaction between excessive noise and reverberation in classrooms has a considerable impact on speech recognition, and hence academic achievement. |
| (Picard & Bradley, 2001) | Reverberation time | | Minor variations from suggested optimum RTs may not result in any detrimental effect. |
| (Towne & Anderson, 1997) | Reverberation time | | Very low reverberation result in reduced audibility of fainter high-frequency consonants. Excessive reverberation could acoustically smear signals. |

On the whole, reverberation time appears to be an important factor in courtroom settings (especially owing to the large physical volume of most courtrooms). Past literature, however, also suggest a moderating effect of ambient noise level. Ambient noise level, in addition to influencing intelligibility, also affects privacy, which is an important factor in most work settings.

5.2.3 Noise level

Noise, or ambient noise (also referred to as background noise) could originate from multiple sources: mechanical systems, light, plumbing, traffic, and adjacent spaces, and are sometimes the softest sound audible in a room (Brooks, 2003). Ambient noise, while interfering with speech in some conditions, has some benefits too. Earlier studies on noise reported by Boff & Lincoln, (1988a) suggest that an important aspect of ambient noise is its ability to mask other sounds in a space (which is implemented in practice in a large number of settings). Masking, on the other hand, also inhibits a person's ability to hear a sound in the presence of other sound that are similar in level and spectrum.

Upward spread of masking occurs when consonants, high pitched word endings and brief words (plurals, past tense, possessive word endings, un-emphasized portions of speech), are masked by low frequency sound (Towne & Anderson, 1997). Depending on the circumstances, masking may or may not be considered as desirable. Nevertheless, masking is an important factor affecting performance. While masking could be part of the acoustics design, fed through the sound system in a space, some noise may originate from

external sources. Timing of such noise seems to matter. The acoustic characteristics of sound occurring close to a known signal in time affects how audible the known signal source would be. Boff & Lincoln (1988b) also point out several other factors that determine the effectiveness of masking noise, including the level of noise and the frequency band of noise. They report that for low noise levels the best masking frequencies are mid or higher frequency sounds. This changes for situations with high noise level, where low frequency noise bands better suit the needs for masking.

Noise, in some occasions with moderator and mediator variables, has been shown to influence many behaviors, some in a positive manner and some negative. The general level of maintenance of the environment has been shown to moderate user response to noise (Lawrence, 1989b). The distance between speakers and listeners also interact with noise levels to influence speech recognition in school settings (Towne & Anderson, 1997). The influence of noise on task performance has been reported in some studies. Such association, however, has been show to be conditional on the complexity of task involved (Gifford, 1997; Lawrence, 1989b). Increase in arousal level resulting from noise has been shown to improve monotonous tasks and those with less cognitive demands. On the other hand, complex tasks, tasks involving multiple sources of information or tasks in multi-tasking environments appear to be negatively influenced by noise. In school settings, external noise (more prominent in shared classrooms) has been shown to lower performance on mathematical and alphabet tasks, as well as in speech perception and reading skills (Picard & Bradley, 2001).

While task characteristics determine the direction of influence of noise, certain characteristics of noise are influential too. In general, relevant (meaningful), uncontrollable, continuous, and unpredictable noise are potentially more harmful to task performance in work settings (Ainsworth & Meyer, 1994; Gifford, 1997). One study demonstrated that intermittent reference noise events (as opposed to general noise level) could be generalized to represent overall annoyance from noise situations in workplaces (Sailer & Hassenzuhl, 2000). Finally, although most studies have typically focused on high noise levels or reference noise events, low noise levels could also have many ill effects including stress (Brooks, 2003). Even in the presence of high background noise, sound signals of lower levels could be audible since the ability to hear is a function of spectrum, location, time, and directionality of human hearing. More details on the references cited are included in Appendix IV, section 4.2.2. Table 5.13 includes summary information of the literature discussed in this section.

Table 5.13: Influence of noise on auditory tasks.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|--------------------------|---|--|--|
| (Boff & Lincoln, 1988a) | Noise | | Ambient noise could be used for sound masking. |
| (Towne & Anderson, 1997) | Noise | | Consonants, high pitch word endings and brief words can be masked by low frequency sound |
| (Boff & Lincoln, 1988b) | Pressure level, frequency band | | Level of noise and the frequency band of noise determine degree of masking. |
| (Lawrence, 1989b) | Noise level, maintenance level, occupant satisfaction | Upkeep of the ambient environment interacts with noise level to determine occupant satisfaction. | Willingness to tolerate sound level of 5 dB higher where respondents are satisfied with the character of the neighborhood. |

Table 5.13 (continued)

| Source | Variables | Hypothesis/ Objective | Conclusions |
|-----------------------------|---|---|--|
| (Lawrence, 1989b) | Noise level, task complexity, performance | | In case of monotonous tasks, high ambient noise level may improve task performance by increasing the arousal level. If the task entails high cognitive demands, higher level of ambient noise may impede task performance |
| (Towne & Anderson, 1997) | Noise level, distance, speech recognition | | Distance and noise influence performance negatively. |
| (Gifford, 1997) | Noise level, task complexity, performance | | Possible moderators include task, task complexity, task intensity, and personality. |
| (Picard & Bradley, 2001) | Noise level, classroom performance | | Classroom noise results in lower performance on mathematics and alphabet tasks. Chronic exposure to high noise level in children lead to significant deficit in speech perception and reading skills. |
| (Gifford, 1997) | Noise, performance, annoyance | | Relevant (meaningful) sound has a greater negative impact as compared to irrelevant sound. |
| (Ainsworth & Meyer, 1994) | Noise, listening performance | To test the effect of noise (continuous and intermittent) on the perception of plosive-vowel syllables. | Increasing noise level affected performance, but the impact was less in the case of continuous background noise. |
| (Gifford, 1997) | Noise | | Unpredictability of noise constitutes an annoyance source. |
| (Sailer & Hassenzahl, 2000) | Reference noise events, annoyance | Even at general low noise level, some reference noise event could lead to the feeling of annoyance. | Reference noise events could be generalized to overall annoyance from the noise situations in workplaces. |
| (Brooks, 2003) | Noise, stress | | Even low-level noise can have many ill effects including stress. |

A significant source of unpredictable noise in courtrooms is from ingress and egress of people especially in the spectator gallery area. Door hardware, seat design, and in some cases floors, create loud, unpredictable sound. Noise produced from impact (as in the case of door hardware) could impede performance, or as suggested earlier improve performance in some cases. In general, it may be suggested that ambient noise benefits as well as impedes performance. Masking offers speech privacy in many situations that need it, where as even low level of unwanted, meaningful, unpredictable sound could produce detrimental results. Further, unpredictable, loud noise from movements could also affect performance, depending on task type. In spaces where speech is the most important auditory task, the ratio of sound level of the signal to the ambient noise level is the deciding factor so far as speech audibility and intelligibility is concerned, which is discussed next.

5.2.4 Signal-to-noise ratio

The S/N (signal:noise) ratio is dependent on (besides the background noise) signal strength, frequency, and the inherent directionality of human speech and hearing. Some of these factors would not matter much in sound reinforced environments, but as discussed earlier, some portions of courtroom proceedings are performed outside the zone of sound reinforcement systems, owing to cultural factors (the activities of lawyers, for instance).

Earlier laboratory based studies involving contrived tasks demonstrated that speech recognition improves significantly with increase in S/N ratio below speech levels of 100 dB (Boff & Lincoln, 1988b). The duration of signal also matters. Below 200 m sec, as the signal duration decreases, the S/N needs to increase to maintain detectability of sound (Boff & Lincoln, 1988a). These findings, however, have less relevance to work settings.

Studies in more realistic settings and some simulated environments reinforce the importance of S/N. In classroom studies, it has been shown that teachers voice presented 10 to 15 dB over background noise level through amplification, resulted in significant improvement in academic achievement and other behavioral benefits (Towne & Anderson, 1997). In a simulation study that manipulated the S/N and reverberant qualities of space, it was shown that influence of S/N on speech intelligibility was significantly higher than reverberation time (Bradley, Reich, & Norcross, 1999), although both factors influence speech intelligibility. Loudness of sound source, sound frequency and directionality of human hearing, however, determine the nature of association between S/N and speech intelligibility. There are, however, limits to the loudness of unaided speech (Boff & Lincoln, 1988b). Further, the frequency of sound constituting speech determines clarity of hearing by the audience (Schijndel, Houtgast, & Festen, 2001). Finally, human speech is directional, and listening abilities could change depending on direction of speech (Brooks, 2003). Literature cited here is elaborated in Appendix IV, section 4.2.3. Table 5.14 includes summary information of the cited literature.

Table 5.14: Influence of S/N on speech intelligibility.

| Source | Variables | Hypothesis/ Objective | Conclusions |
|--------------------------|--|--|---|
| (Boff & Lincoln, 1988b) | S/N, speech recognition | | Recognition of speech improves with increase in the signal to noise ratio. |
| (Towne & Anderson, 1997) | S/N, speech intelligibility | | Classrooms where teacher's voice is presented 10 to 15 dB over background noise level, a significant improvement in academic achievement and other behavioral benefits results. |
| (Bradley et al., 1999) | S/N, reverberation time, speech intelligibility | The combined effects of a wide range of S/N ratio and room acoustics conditions on speech intelligibility. | Both S/N ratio and reverberation time influence speech intelligibility. Influence of S/N ratio significantly larger. |
| (Boff & Lincoln, 1988a) | S/N, signal duration, signal detection | | Duration of signal as well as the signal to noise ratio influence the detectability of a tone in noise. |
| (Schijndel et al., 2001) | Speech intensity, time, frequency, speech perception | Observe their impact of frequency on speech perception. | Distorted coding of spectral information (frequency) of source signal had the largest influence on speech intelligibility |

In the context of courtrooms, signal strength (and S/N ratio) is important for situations where the speech is not electronically reinforced. As suggested in the studies cited above, long-term average level of human speech is about 60 dB (A) at one meter from the source. In free field conditions (as in outdoor situations, or in very large room, and more specifically rooms with very absorbent surfaces) the sound level decreases by about 5 dB for every doubling of distance. Distance between speaker and listener could, hence, constitute a significant variable in large courtrooms.

On the whole, the strength of signal, level of background noise, duration of signal, frequency of interest, and direction of incoming signal vis-à-vis the listener appears to influence speech and hearing tasks. A related issue is of distance, especially in speech without electronic reinforcement.

5.2.5 Distance

Especially in conditions where speech is not reinforced, distance between speakers and listeners influence task performance considerably. The effect of distance on recognition scores of children in classroom settings has been discussed earlier (Towne & Anderson, 1997). This brief section was intended only to highlight the importance of this variable (and its possible impact in courtroom settings).

Many other factors seem to influence performance in the acoustic environment, but lesser studied. Those are discussed next.

5.2.6 Visual cue

It is commonly understood in acoustics design that good sightlines result in good acoustics. While that is mostly discussed in auditorium design, it is also relevant in courtroom settings, for good listening conditions. Boff & Lincoln (1988b) articulate this point further by citing laboratory studies that show that intelligibility of speech could be raised from unintelligible to intelligible level by enabling lips reading, even when visual

and auditory information are incompatible. They further state that intelligible signals can be obtained by combining intelligible lip-reading cues with intelligible speech.

5.2.7 Binaural versus monaural hearing

Whether one is listening through one ear or both the ears, appears to make significant differences in some situations. This situation could arise from physiological defects, or from limits to available hearing aid technology. Boff & Lincoln (1988a) point out that in monaural hearing, the threshold of detection is about 3dB higher than in binaural hearing. In other words, binaural hearing is more sensitive to sound detection. The difference in sensitivity also appears to be dependent on the frequency of the incoming sound. While some courtroom users use headphones for better listening conditions (as in the case of the reporter), prevalent courtroom technology, generally, do not include any monaural listening conditions, and the factor may not be relevant to courtroom settings.

5.2.8 Echo and other long delayed reflections

In addition to factors discussed above Lawrence (1989b) points out the detrimental effect of echo and other long delayed reflection of sound. Flutter echo and creep are other kinds of reflection that are regarded as problems in spaces where intelligibility of speech is considered important. In many settings, echo and similar long delayed reflections are, however, intentionally used to produce special effects. Instances include a singer wanting a barely audible echo. In most other situations echo is generally undesirable (Brooks,

2003). Echo is a distinct reflection of an original sound source, after the source has stopped. Unlike early reverberation, which reinforces sound and hence desirable in many situations, echo interferes with sound.

5.2.9 Vibration

Human performance is affected by vibration produced by sound waves too (Lawrence, 1989b). Sources of vibration include wind pressure (creating vibration especially in tall buildings), structure-borne sound waves, and dragging of furniture on light weight floors and footsteps. Structure-borne sound could originate from mechanical plants and ducts, as well as transportation corridors. Further, structure borne vibration can produce disturbances in air, leading to audible sound. Transformers, and ventilation machinery in buildings can also produce vibration that can influence listening conditions in workspaces (Brooks, 2003).

5.2.10 Age/ hearing ability of listener

Age and hearing ability of listeners has been shown to influence hearing performance. Hearing ability is the best in young adults, and decline as one gets older (Boff & Lincoln, 1988a; Lawrence, 1989b). Young adults have even better hearing abilities than children. In older age, the loss of hearing is greatest in the higher frequencies. Especially, in environments having interferences from other noise sources, Boff & Lincoln (1988b) point out that age is an important factor in speech intelligibility. They cite laboratory

findings to suggest that younger subjects have better ability to overcome the interference effects of noise. Further, the authors cite studies dealing with perception of speech. With age the perception of degraded speech declines, which is more pronounced in the fifth decade of the life span and later. The same holds true, according to them, but to a lesser extent, for normal speech. Gifford (1997) suggests age as a moderator in the association between noise and performance. Citing previous studies in literature, he suggests that noise slows reaction time and harms memory of older people more than younger people.

5.2.11 Gender

Gender appears to be a factor in age-related hearing loss. Boff & Lincoln (1988a) report that men are affected more than women in losing hearing abilities with age. In addition, Boff & Lincoln (1988b) suggest that in terms of speech pressure there are gender differences too. They report that based on laboratory experiments it has been observed that, on an average, the sound pressure level of female speakers is about 3dB less than the sound pressure level of male speakers. Beside gender differences in speech pressure level, there are differences in intelligibility. Bradlow, Torretta, & Pisoni (1996) used a multi-talker database containing intelligibility scores for 2000 sentences to identify talker-related correlates of speech intelligibility. Results suggest that female talkers are more intelligible as a group than male talker. Further, there are significant differences between the speech frequencies or spectral tilt of male and female speaker in both consonants and vowels (Hanson & Chuang, 1999; Whiteside, 1998a, 1998b).

To conclude, reverberation time, noise level, signal-to-noise ratio and distance have been shown to influence tasks involving speech recognition and comprehension. In addition, visual cue, binaural vs. monaural hearing conditions, echo and other long delayed reflections, vibration, age, and gender are also hypothesized to influence auditory tasks.

5.3 Interaction studies

Studies on interaction between light, noise, and heat (or a subset of the three) have surfaced in journal literature lately. Temperature alone has been the subject matter of some literature. In field studies the most comprehensive discussion is provided on office environments by Gifford (1997). He introduces the notion of ‘effective temperature’, which is a combination of air temperature, humidity and air movement (that, in combination, affect the thermal comfort conditions of users), which, he informs, has replaced temperature measurements in most research. Studies on the influence of temperature on task performance suggest that task complexity, clothing conditions, and duration of task moderate the association between the two variables (Gifford, 1997; Hedge, 2000). Some design guidelines suggested by these literatures, and elaborations of studies mentioned in the subsequent paragraphs are included in Appendix IV, section 4.3.

Several studies have investigated performance (problem solving, cognitive tasks) and the influence of luminous, auditory and thermal variables on performance. Most studies have reported significant association between one or more of the environmental variables on performance. Noise and illuminance has been shown to influence free recall tasks (Hygge

& Knez, 2001). Noise and luminance influence feeling of fatigue in laboratory conditions (Takahasi et al., 2001). Other studies show that spectral quality of light and noise impair cognitive performance (Knez & Hygge, 2002). Noise and temperature, combined, has been shown to influence subject's perception of thermal comfort (Pellerin & Candas, 2003).

These studies provide evidence that the association between user behavior and environmental parameters may not be as stratified as assumed in traditional studies, where environmental parameters were studied in isolation. Traditional researches on environment were generally single parameter studies. Recent studies involving multiple parameters are relatively small in number and are too few to draw any major conclusions about interaction effects among environmental variables, and their influence on task performance. Nevertheless the significant findings in the few studies discussed here suggest that environmental variables interact in significant ways to affect user behavior. The literature cited in this section are elaborated further in Appendix IV, section 4.3, and summarized in table 5.15.

Table 5.15: Interaction studies on the environment and human behavior.

| Source | Variables | Hypothesis/Objective | Conclusion |
|---------------------------|--|---|--|
| (Gifford, 1997) | Temperature, performance | | Association between temperature and performance is moderated by task complexity |
| (Hedge, 2000) | Temperature, humidity, satisfaction | | Variations in humidity had little impact on satisfaction, where as temperature variations from an optimum of 20 deg C leads to rapid change in satisfaction level. |
| (Hygge & Knez, 2001) | Noise, temperature, illuminance | Investigate the interaction between noise, heat and illuminance on attention, memory and problem solving. | Results varied depending on task type |
| (Takahasi et al., 2001) | Noise, luminance, cognitive performance | Study the combined impact of impact of noise and luminance on cognitive performance and feeling of fatigue. | Self reported fatigue scores increased under noisy conditions. |
| (Knez & Hygge, 2002) | Illuminance, lamp type, noise, cognitive tasks | Influence of light color and meaningful noise (speech) on cognitive performance. | A main effect of noise and lamp type. |
| (Pellerin & Candas, 2003) | Noise, temperature | Combined effect of noise and temperature on subject's estimate of the thermal and acoustical environment. | A combined effect of noise and temperature in warm conditions. |

5.4 Scope of the Study

The study developed a modality to link as-built data and evaluation data in a single, unified semantic structure. It also addressed a long time necessity to feed EB knowledge to the design decision-making phases, in addition to creating a system that supports real-

time discovery process by enabling hypothesis generation and testing based on the most up-to-date data. It provides an avenue for knowledge dissemination, and a source of supplementary knowledge to support decision-making during design and design review. Considering the wide range of courtroom types and factors that could possibly influence performance in courtrooms, the study limited itself to the following:

- Courtroom Types: Data collection for database instantiation and demonstration are limited to physical, environmental, user, and performance data from trial courtrooms. More specifically, the data was limited to District Regular courtrooms, Magistrate Judge courtrooms, and Special Proceedings courtrooms in Federal courthouses, and Superior Court courtrooms in state courthouses. It should, however, be mentioned that cases involving other courtroom types would not, theoretically, pose any issue of incompatibility.
- The state Superior Courts included in this study are specific to the State of Georgia.
- The variables considered in this study are the ones hypothesized to influence performance in a courtroom setting. Such variables include those related to sizes, shapes and other physical characteristics of courtrooms and courtroom elements, factors in the visual environment, and factors in the auditory environment. Factors affecting security are outside the scope of this study owing to logistic reasons.
- Evaluation or performance data in this study is limited to user's evaluation (POE) of the courtrooms they work in. The POE type is one where a questionnaire (paper based or web-based) survey is administered on users of a setting. The

questionnaire survey could be a one-time administration (after a period of occupation) or a regular, recurring, one.

- Phases of a case/proceeding that occurs outside of a courtroom are excluded from this study.
- Modeling efforts are geared towards information support at the design and the design review phases of a building procurement cycle. In addition, the data structure supports discovery processes in academic inquiry. In building design and procurement processes, early design (Masat, 1996; Wiezel, 1996; Preiser, 2001) and design review phases allow easiest changes, and hence the focus in this study.
- The structure of POE considered for this study (and hence the kind of data collected) is restricted to the type of data that a small team of POE investigators would reasonably be expected to collect on site on a single visit lasting a couple of days. This reflects the typical team composition and duration of POE studies, and the objective in this study is to retain closeness to reality in logistic and financial terms.
- Although various forms of representation of feedback from the data model are shown as outcomes, issues related to the appropriateness of such representations is not within the scope of this study.
- Interface design and programming is not a part of this study. A working interface is developed with external help to only support the demonstration of study outcomes.

- Finally, the focus of the study is on developing a method for information support and discovery. This study does not create a design support tool.

5.5 Summary

Several luminous and auditory environmental factors as well as individual characteristics have been shown (or hypothesized) to influence visual and auditory task performance. In visual task performance, factors that have been consistently shown to influence visual tasks, include illuminance, light direction, luminance, glare, visual contact with exterior, viewing distance, time period of exposure, age, thermal conditions, and screen position. Findings from studies on some other hypothesized variables have not been consistent, including spectral power distribution and screen flicker. In auditory task performance reverberation time, noise level, signal-to-noise ratio and distance have been shown to influence tasks involving speech recognition and comprehension. In addition, visual cue, binaural vs. monaural hearing conditions, echo and other long delayed reflections, vibration, age, and gender are also hypothesized to influence auditory tasks.

The scope of the study is limited to physical, visual and auditory factors, and corresponding users evaluations, in federal and state trial courtrooms. Modeling outcomes are focused on the design and design review phases of a building's procurement cycle.

Chapter 6

Method

The range of physical and environmental factors that might affect performance of courtroom proceedings and tasks were outlined in chapter 4 and 5. This chapter describes four areas of this study: 1) variables or data types that were included in the study and reasons for excluding certain variables, 2) way the variables were measured, 3) data collection tools, and 4) sample of courtrooms from which data was collected. This chapter includes:

6.1 Data types

6.1.1 Factors in the visual environment

6.1.1.1 Task illuminance

6.1.1.2 Task brightness

6.1.1.3 Background brightness

6.1.1.4 Surrounding brightness

6.1.1.5 Glare

6.1.1.6 Light direction

6.1.1.7 Spectral power distribution

6.1.1.8 Screen illuminance

6.1.1.9 Screen luminance

6.1.1.10 Sightline obstruction

- 6.1.1.11 Variables not included in this study
- 6.1.2 Factors in the auditory environment
 - 6.1.2.1 Reverberation time
 - 6.1.2.2 Background and movement noise
 - 6.1.2.3 Variables not considered in this study
- 6.1.3 Other Variables
 - 6.1.3.1 Temperature and relative humidity
 - 6.1.3.2 Distance between people in the well area
 - 6.1.3.3 Variables not considered in this study
- 6.1.4 Physical data types
 - 6.1.4.1 Courtroom
 - 6.1.4.2 Courtroom spaces
 - 6.1.4.3 Courtroom elements
- 6.1.5 User data types
 - 6.1.5.1 User age
 - 6.1.5.2 User gender
 - 6.1.5.3 User role/ position
 - 6.1.5.4 Vision and hearing deficiencies
- 6.1.6 Evaluation data types
- 6.2 Data collection instrument
 - 6.2.1 Survey questionnaire
 - 6.2.2 Data collection protocol
- 6.3 Sample

6.3.1 Selecting courtrooms

6.3.2 Questionnaire response

6.4 Summary

6.1 Data types

A large number of variables identified through literature survey were included in the data collection protocol and user questionnaires. Those data types could be classified into two broad categories: 1) descriptive physical and environmental data, and data on users, and 2) evaluation (POE) data. The following description starts with the former data types.

The physical data types pertain to physical/spatial characteristics of the courtroom and courtroom elements, principally those related to sizes, shapes and locations.

Environmental data types could be grouped into the general domains they are related to:

1) visual environment, and 2) auditory environment. The following sections discuss each data type, reasons for exclusion from the study in case a variable was excluded, and the method and instruments used for measurements.

6.1.1 Factors in the visual environment

Literature on visual environment based in experimental settings and field studies in schools and offices have, as discussed earlier, highlighted several factors that might affect visual tasks. All field measurements related to the luminous environments were

conducted after taking certain steps to obtain the most meaningful data. Before taking any measurements the court staff was instructed to set the courtroom lighting to the level that is generally set during courtroom proceedings. This step is more relevant in the case of federal courtrooms and some newly constructed state courtrooms that allow multiple light settings. It was found that despite the various levels of light setting permitted by modern electrical fixtures and controls, judges generally use two types from the range of settings available: one setting type for general courtroom proceedings, and a second type for audiovisual presentations. All measurements were conducted under the general (courtroom proceedings) lighting conditions. Variables related to visual tasks included in the study are summarized in table 6.1. Succeeding sections explain each variable in details:

Table 6.1: List of variables related to visual tasks included in the study.

| Variable | Operational Definition |
|---|--|
| Task Illuminance | Illuminance measured on the plane of interest |
| Task brightness | Luminance of task surface |
| Background brightness | Luminance of the surface in the vicinity of a task |
| Surrounding brightness | Mean brightness of the surfaces within the general cone of vision within which a task is performed |
| Glare (maximum brightness: task brightness) | Surrogate definition of glare adopted is the ratio of task luminance to luminance of the brightest large surface |
| Vertical Illuminance | Illuminance measured on the vertical plane at each user location |
| Spectral quality, View (Window area) | Presence or absence of natural light used as surrogate (dichotomous) measure of spectral quality of incident light, and view |
| Screen illuminance | Illuminance measured on the screen plane |
| Screen luminance | Brightness of computer screen measured from the user location |
| Sightline Obstructions | Number of locations in the well to which sightline is obstructed from each location of interest |

6.1.1.1 Task illuminance

Task illuminance is generally accepted as a key factor influencing performance of visual tasks. Studies, however, suggest that the association between task illuminance and performance may not be linear, and may follow the laws of diminishing returns. It has also been suggested that the association is moderated by several task characteristics. Considering the importance of such propositions task illuminance was included as a data type. In this study, task illuminance means the illuminance measured on the plane of interest for each location in the courtroom. Typically, the plane of interest is horizontal. In some locations, however, the plane could be inclined (as in Lecterns).

Task illuminance was measured using an EXTECH Instrument's Foot Candle/Lux (Illuminance) Meter (Figure 6.1). For measuring the illuminance on the bench, deputy/clerk's work station, reporter's work station, and witness box the sensor of the Illuminance Meter was placed roughly six inches from the edge of the work surface, and located centrally along the length of the work surface. Six inches from the edge was considered (in this study) to be the central region of a visual task target (reading documents, writing, etc.). There were cases where a single (combined) workstation was provided for two users (for instance the reporter and the deputy/clerk). In such cases the length of the workstation was equally divided (for maintaining uniformity across observations) and the center of each half was considered for measurement of task illuminance. Some elements and space zones in the courtroom have multiple occupants. Those include the lawyers, jury box, and the gallery. To minimize data collection efforts

certain decisions were taken in advance to reduce the complexity of measuring data from multiple user zones. For the lawyer's tables, only the government attorney's positions were targeted. This was done keeping in view that such users were the only lawyer type to whom questionnaires could be administered. Generally, a lawyer's table includes seating capacity for two or three lawyers. It was, however, found during field observations that the lighting conditions do not vary in any major way between the lawyer locations on each table, and the attorney position closest to the jury box was adopted as the measurement location for illuminance, and all other lighting variables. A similar strategy was adopted for the jury box. In all cases the illuminance at the mid point of the jury box on the first row of seating was measured (jury boxes typically range between one to three rows). The sensor was placed on the top of the middle jury seat for recording the measurement. In case of jury boxes with even number of jury seats in a row, average value of the middle jury seats was used. Lighting measurements in the gallery also followed rules for rendering uniformity across measurements. The central row of the gallery was always targeted. In case of even number of rows, the middle row closer to the well was targeted. This was done assuming that people in the gallery would occupy the rows closer to the well first before occupying the rows located further away. Depending on the courtroom layout, the gallery seating could have two or three sections along the main axis defined by the entrance and bench (or other elements in corner bench locations). The middle seat (or mid point in case of bench type seating) of the middle row in each section was targeted for measurement and the mean value of measurements was recorded for analysis. Figure 6.2 illustrates the locations where illuminance and other variables related to visual tasks were measured.



Figure 6.1: EXTECH Instrument's Foot Candle/Lux (Illuminance) Meter.

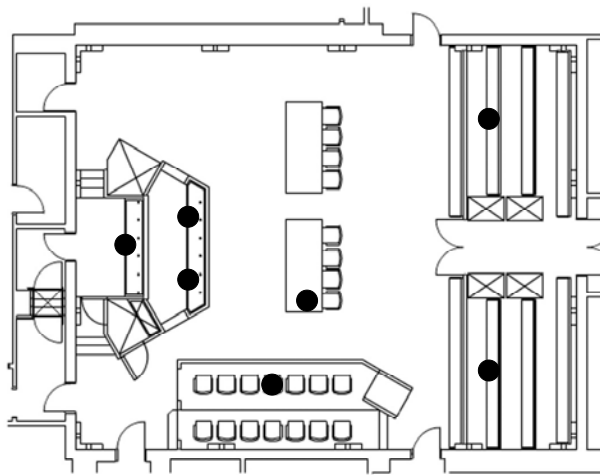


Figure 6.2: Black circles represent courtroom locations where lighting measurements were conducted.

6.1.1.2 Task brightness

Brightness in this study refers to the luminance of surfaces measured on site. Brightness of task has been mostly discussed in the context of brightness ratios or luminance ratios

between the task, background and the surrounding. It has been suggested that the brightness ratios might be more influential as compared to illuminance in many circumstances of task performance. Accordingly the task brightness was included as a variable in the study.

Luminance of surfaces was measured using a Minolta CS-100 luminance meter (Fig.6.3). Task luminance was primarily measured at courtroom locations with workstations. Those locations include the bench, the reporter station, deputy/clerk station, attorney table and, wherever provided, workstation for the security staff. Luminance was measured at the same locations as described for illuminance measurement (see figure 6.2). For task luminance a sheet of white paper (letter size) was placed on the desktop at the exact location where illuminance was measured. Using the Minolta CS-100, luminance data was collected and entered into the site visit protocol. The measurement was taken from a seated position (by the investigator) at a location centered on the work surface length and at a distance that might be reasonably be considered as representative of most working postures.



Figure 6.3: Minolta CS-100 Luminance Meter used in the study.

6.1.1.3 Background brightness

Background brightness in this study was considered as the luminance of the surface in the vicinity of a task. Since task and background brightness are almost always considered together in the form of a ratio, background brightness was included as a variable. It was measured only for courtroom locations for which task luminance was measured, and with the same instrument. The background luminance was measured by aiming the instrument towards locations within the immediate vicinity of the white paper from which task luminance was measured. Measurements were taken from the same position as described for task luminance. In most cases the luminance measurements did not vary in any major way across the locations in the immediate vicinity of the white paper (within 10 to 15 cd/m^2). In some cases the differences were more, owing to reflections of light fixtures or direct down light from the ceiling. In such cases the mean value of the minimum and maximum luminance was recorded.

6.1.1.4 Surrounding brightness

Mean brightness of the surfaces within the general cone of vision within which a task is performed was considered as surrounding brightness in this study. Measuring surrounding brightness involved greater complications. Courtrooms are large spaces with different kinds of surfaces and surface luminance. Lighting literature recommends a weighted aggregate measure of the different luminance values (Rea, 2000). In other words, the range of luminance values in the field of vision need to be weighted depending on the size of the surface and then aggregated. This method is manageable for theoretical modeling, but pose a logistic problem for field applications. Further, the investigator did not have access to instruments that would precisely define the theoretical field of vision from any particular location. In most empirical studies where surrounding surface luminance has been measured, the settings have generally been experimental, meaning that exact luminance values of surrounding could be measured in precision. Field studies do not enjoy such benefits.

To create a simpler process, that is amenable to field measurements, the courtroom was divided into four or more surfaces (based on courtroom shape), where each wall was considered as a separate, complete surface. It was assumed that the surface towards which a user is generally oriented (walls to which the seat faces) is the surrounding for the user's visual field. Exact area of changes in wall surface characteristics was not possible to measure. The (unweighted) average of various luminance values of a single

wall surface was recorded as the luminance value of that surface (and the surrounding luminance of the users facing the wall).

6.1.1.5 Glare

The ratio of task luminance to luminance of the brightest large surface was considered as a surrogate definition of glare for this study. The reasons for doing so are many.

Measuring glare in field studies is an extremely complex task. There has been substantial theoretical works on measuring glare, which has resulted in a number of glare indices. All researchers working on creating indices, codes and recommendations agree on the underlying assumption that glare is dependent on four main factors:

- The luminance of the source
- The size of source (solid angle subtended in the user's eye)
- The position of glare source – the angle in the visual field at which it is located, and,
- The luminance of the surrounding

Based on these assumptions researchers have developed numerous mathematical models to capture the complexity of glare. From a POE viewpoint (measuring glare on site), however, several problems arise, should one develop a protocol based on the mathematical models. Those include:

- Instrumentation: instruments to measure precise solid angles are not available.

- Measuring the precise angle at which a source is located is also a problem – although it could possibly be measured through a luminance meter mounted on a tripod that is improvised to measure angular dimensions. This is also compounded owing to the next problem area discussed.
- Additive nature of glare: it is assumed in literature that glare sources are additive. In other words glare $G = g_1 + g_2 + g_3 \dots$. For a POE team it may not be practically feasible to measure all potential glare sources (based on mathematical models).
- Brightness constancy (a phenomenon discussed earlier): casts some doubt as to whether objective measurements made through instruments corresponds to the subjective impression of glare in an environment with relatively less variations in brightness of surfaces and sources. Brightness constancy may act to modify perceptions.

It was, thus, considered impractical to develop a protocol based on any of the mathematical models associated with glare measurements. The investigator decided not to study 'glare' per se, since logistics of site measurements created insurmountable problems in order to confirm to the definition of glare in engineering models.

Other possible means to capture the underlying essence of glare, without using the term 'glare', was investigated. The investigator reviewed the fundamentals behind the causes of glare sensation such as those provided by Stein & Reynolds (2000). In a simple situation where a high brightness source is present (say a window) and a person is

conducting a task that is placed in a low brightness environment, three visually disturbing phenomena occurs:

- Eyes adapt to a higher luminance level (depending on the size of the source – the size needs to be large enough to occupy a substantial portion of the retina).
- The eyes are naturally (involuntarily) drawn (owing to biological reasons) to the brightest area in the visual field. However, the task is also important, and the eyes are voluntarily drawn to the task. This causes tension.
- The eyes keep getting attracted to the brightest region involuntarily, and back to the task voluntarily. That is, theoretically, the main cause of stress associated with glare.

In view of the theoretical arguments, one could look at glare as the result of brightness difference between the task and the brightest region in the visual field (a region defined by 60 degrees around the axis perpendicular to the retina). Some additional attributes of space also influence glare. The size of the source also matters. Thus large sources of lower luminance are more harmful than small (point) sources of high luminance. This is because the point sources are not large enough to occupy any substantial area of the retina.

A typical courtroom has three main types of light sources: 1) natural light from windows, 2) direct light from numerous point sources, 3) indirect/diffused light from large areas – domes, coffers – in the ceiling. Out of these three, the point sources are small enough not to produce any tension in the visual field. To simplify the measurement of glare (without naming it as glare – but agreeing with the fundamentals, to retain some association

between field measurements and the mathematical models) it was decided to do the following:

- Measure the luminance of the task
- Check the normal cone of vision (subjective) – and identify large areas of high luminance from each location of interest.
- Check the luminance of each of the large areas of brightness.
- Record the luminance of the brightest of the large areas (note that definition of source size is dichotomous – small, point sources, and large sources).
- The ratio of task luminance to luminance of the brightest large surface was considered for the study.

In adopting this strategy, the measurement of the luminance (brightness) is objective, but the measurement of area of source (solid angle), and angle at which the glare source is present remains subjective. For the purpose of this study this variable will be referred to as the “maximum brightness: task brightness” ratio.

6.1.1.6 Light direction

Illuminance measured on the vertical plane at each user location (figure 6.2) is considered to capture the effect of light direction in this study. Direction of light has been mostly discussed in the context of face recognition (chapter 5). Studies on face recognition identify the shadow-creating properties of light direction as a variable influencing recognition of faces. Experiments cited in previous chapters involved changes in lighting direction between top and bottom, and two sides. In field situations, such as a courtroom,

the light direction is mostly from top. However, reflected light from walls also constitutes an important source of side lighting. In addition when courtrooms are provided with windows (on the walls), side lighting could be substantial. Light from top is captured through measurement of horizontal/task illuminance (section 6.1.1.1). Side lighting was captured through the measurement of vertical illuminance. Vertical illuminance was measured using the illuminance meter (figure 6.1). To maintain uniformity in measurement, a clipboard was placed vertically at each location where illuminance was measured. The sensor of the illuminance meter was hung from the top of the clipboard resting against the vertical surface, and the level of illuminance recorded. The ratio of the horizontal to vertical illuminance at all locations constitutes the variable of interest.

6.1.1.7 Spectral power distribution

Presence or absence of natural light is used in this study as a surrogate (dichotomous) measure of spectral quality of incident light. The reasons for using a surrogate measure are many. Spectral power distribution, as discussed earlier, has been the focus of numerous studies. Many studies vary a known value of the CRI in experimental settings under the hypothesis that certain color rendering values (mostly those closer to daylight) are more beneficial as compared to others in working environments. Yet other studies have focused on the color temperature, and some on both. But the basic assertions remain the same that relates color temperature or CRI of light sources simulating daylight to better outcome. In field setting like courtrooms, color temperature is a more pertinent measure as compared to CRI. The reason being that in field settings the resultant incident

light is the aggregate of light from various sources (with different CRIs). There is no instrument to measure the aggregate CRI of different light sources. Aggregate color temperature, on the other hand, could be measured using commercially available instruments. This variable was, however, not included in the study owing to two reasons. The inconsistent findings in the literature on the impact of light color on behavior constituted one reason for non-inclusion. Secondly, the study logistics did not permit the renting of instruments to measure color temperature. It was decided to incorporate this variable as a dichotomous one – courtroom with and without natural light. It is assumed that if the color characteristics of light indeed influence behavior, it should also reflect in the dichotomous measurement of courtroom lighting.

Considering that some studies on classrooms have shown association between daylight and performance, it was decided to measure another parameter related to daylight – window area. This was decided since studies also point out the relationship between window area and performance in schools (Chapter 5). Window area relates both to the amount of daylight and the amount of view.

6.1.1.8 Screen illuminance

Illuminance measured on the screen plane is considered as screen illuminance in this study. Illuminance as a variable in screen-based tasks has been discussed in terms of workstation illuminance. Measurement of workstation illuminance is already covered in section 6.1.1.1. However, since screens are generally positioned at a different angle as

compared to desktops, it was considered prudent to measure the illuminance level at the plane of the screen surface. The illuminance meter was used for this purpose. The screen position (as found during site visit) was not changed assuming that such positions represent the general condition in which the screen was viewed. Measurement was conducted by resting the sensor of the instrument on the screen (approximately at the center of the screen).

6.1.1.9 Screen luminance

Brightness of computer screen measured from user locations is considered as screen luminance in this study. Screen luminance is a factor frequently discussed in literature as an important variable influencing screen-based task. Screen luminance was measured from each user position using the Minolta CS-100 luminance meter, with the probe aimed at the center of the screen.

6.1.1.10 Sightline obstruction

Sightline obstruction is defined as the number of locations in the well to which sightline is obstructed from each location of interest (expressed in percentages). Good or unobstructed sightlines are generally considered to be good for visual as well as auditory tasks. In a courtroom there are multiple sources of sightline obstructions, owing to the design of courtroom elements, millworks, and technology components. The study recorded the number of locations within the well to which sightlines were fully or

partially obstructed. This was measured at the same user locations in the well from where luminance measurements were conducted. The resultant data was recorded as a percentage of all key positions in the well area that suffer from sightline obstructions from each location.

6.1.1.11 Variables not included in this study

Several other variables were identified in chapter 5 as influential in conducting visual tasks. The variables not included in this study are covered in this section along with reasons for not doing so. Variables not considered include size of detail and time of exposure, flicker rate, and distance and viewing angle in screen based tasks.

Many earlier laboratory studies on visual acuity underscore the importance of size of detail and time of exposure of stimuli as important variables influencing task performance. However, the tasks involved in those studies were mostly contrived, and very dissimilar compared to tasks performed in courtrooms. It can be argued that the time of exposure of a task (document, objects, people) is not an important factor in courtroom proceedings, although it could be important in aeroplane cockpits. The same observations could be made about the size of details. Size characteristics of most tasks in a courtroom are standardized through regulation (see USDC, 2002, for instance). In view of these observations size of detail and time of exposure was not included in the study.

Several studies have included screen flicker rate as a variable. Results of such studies, however, have not been consistent (see chapter 5). Flicker rate as a variable was, hence, not included in this study.

Finally, as discussed in chapter 5, experimental studies have shown viewing distance and viewing angle to the screen as important ergonomic factors. In most courtroom workstations modern flat-panel, lightweight monitors enable changing monitor positions easily. Similarly, heights of desktops do not vary much across courtroom elements, and height adjustable chairs provide users with the choice to change heights (and hence viewing angles) easily. Owing to the flexibility built into modern hardware and systems, it was difficult to find a reliable way to measure such factors in field situations. Further, considering the flexibility afforded by users, such factors might not play an important role in the user's rating of their environment.

There are some locations in the courtroom where viewing distance and angle could be an influential factor. One example of such locations is the jury box. Monitors in the jury box are generally fixed to the jury rail, thus resulting in an unchangeable distance and vertical viewing angle for the jury members. Monitors and other electronics (like microphones) in the witness stand are also generally fixed to the furniture to prevent their use in any violent manner. The study, however, was designed under the assumption that jurors and users of witness box would not be available for the survey. Owing to these considerations, distance and viewing angle (as related to computer screens) was not considered in the study.

6.1.2 Factors in the auditory environment

Compared to the visual environment, studies in the area of acoustics are relatively fewer. Available studies, nevertheless, underscore several environmental factors that might influence speech and hearing tasks. Variables in the auditory environment considered in this study are outlined in table 6.2. The succeeding sections outline each variable in further details, and provide reasons for exclusion, where appropriate.

Table 6.2: List of variables related to auditory tasks included in the study.

| Variable | Operational Definition |
|--------------------|--|
| Reverberation time | Arithmetic average of the reverberation times measured at 250, 500, and 1000 Hz |
| Background Noise | NC-rating from observed measurement of ambient sound pressure levels |
| Movement Noise | Mean of sound pressure levels measured at 250, 500 and 1000 Hz, during movement in gallery and public entrance |

6.1.2.1 Reverberation Time

The arithmetic average of the reverberation times measured at 250, 500, and 1000 Hz is considered as the reverberation time of courtrooms in this study. Reverberation time and background/ambient noise are the most frequently studied factors in experimental as well as field studies. It has been shown that both factors influence speech and hearing. It could be argued that reverberation time changes in a room depending on where it is measured. In most practical circumstances, however, the difference in reverberation time between the locations may not be large enough to warrant separate measurements at each location

of interest in a courtroom. As Brooks (2003) pointed out in the context of measuring sound systems in a room, “reverberation time is (theoretically) similar throughout a room. The only reason for taking point-to-point specific measurements in a room is scientific curiosity. Design is served well enough by more general measurements and observations.”

In view of Brook’s observations, reverberation time was measured at one single location in each courtroom. Typically that location was a central location in the well. The measurements were taken using a Larson Davis 800-B sound meter (figure 6.4), and measurements were recorded at the center frequencies for each band of 1/3 octave. The measurement used for the analysis (described later) uses only the recorded time at 250, 500 and 1000 Hz center frequencies. This was decided owing to the fact that the study was more concerned about the frequencies related to human speech. This is supported by Bradley, Reich, & Norcross (1999) who point out that mid-frequency RT (RT at 1000 Hz) measures can be very effective in field studies. The aggregation of the measurements at the three center frequencies was done by calculating the arithmetic average of the values.

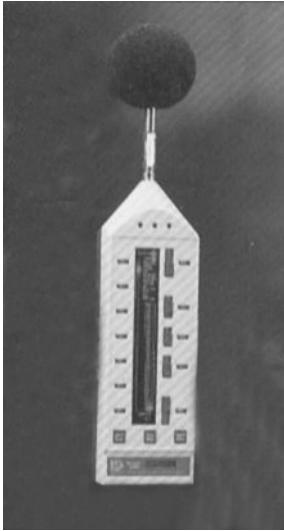


Figure 6.4: Larson Davis 800B used in the study to measure acoustical parameters.

6.1.2.2 Background and movement noise

NC-rating from observed measurement of ambient sound pressure levels in vacant courtrooms is defined as background noise in the study. The mean of sound pressure levels measured at 250, 500 and 1000 Hz, during movement between gallery and public entrance, is considered as movement noise in this study. As pointed out in chapter 5, the ambient/background noise has been shown to be an important variable in experimental as well as field settings, and was considered an important variable in this study. Sound pressure level of ambient noise was measured with the same instrument and at the same location as reverberation time. Considering one location per courtroom also followed Brooks's (2003) observation that “the background noise... is fairly level throughout a room as soon as you get away from a particular source, such as an air supply grill.” Background noise for each courtroom was recorded for each 1/3 octave center frequency (63, 125, 250, 500, 1000, 2000, 4000, and 8000 Hz) in vacant courtrooms. The noise that

was captured in the measurement included those from lighting and mechanical systems as well as external sound from lobbies and other spaces. Sound level measurements during typical courtroom proceedings in occupied courtrooms would probably provide more meaningful data, which, however, was not possible. NC-rating derived from observed measurements was used in the study.

A second type of noise was also measured during the field studies. This was designed considering the fact that the noise levels measured excluded noise generated by people in the courtroom. During initial ethnographic studies of courtroom proceedings it was observed by the investigator that the most salient noise source in occupied courtrooms is the door hardware. This is truer in the gallery and the public entrance where people move in and out of the courtroom more frequently during a session as compared to doors in the well. It was decided that the noise generated by opening and closing of the public entrance doors and movement within the gallery seats, be measured to see if it indeed had any impact on speech/hearing conditions. For this purpose noise levels only at 250, 500 and 1000 Hz were measured. The instrument was located at the same location as for the other acoustical measurements. The peak sound level was measured as the investigator moved from the public area outside the courtroom to the gallery seats. The mean of the three values was used for the data representation and analysis.

6.1.2.3 Variables not considered in this study

Some influential auditory variables identified in chapter 5 are not included in this study, including signal-to-noise ratio, signal duration, signal frequency, echo and vibration. The reasons for not including those variables are explained below. Signal: noise ratio, signal duration, signal frequency have been shown to be important in earlier studies. Out of the three, signal duration is not relevant to this study, although it could be relevant in other settings. Signal to noise ratio has been shown to be important in school settings.

However, it was not possible to record measurements during actual courtroom proceedings. The same is true for signal frequency. Nevertheless, for parts of the courtroom proceedings that are of interest (those involving un-amplified speech), speech frequency and pressure level is known for the general population, and was considered appropriate to serve as proxy values for any hypothesis testing, if necessary. None of these values were actually measured on site. Finally, echo and vibration were not measured during site observations due to lack of access to appropriate instruments. The factors were noted during site visits, but no objective measurements were recorded or used.

6.1.3 Other variables

Studies cited earlier have shown many aspects of the thermal environments to be influential. In addition, distance was considered important to visual and auditory tasks,

but was represented by surrogate measures in this study. The variables are summarized in table 6.3.

Table 6.3: Other variables related to visual and auditory tasks included in the study.

| Variable | Operational Definition |
|-------------------|---|
| Temperature | Temperature recorded at the center of the well in an unoccupied courtroom |
| Relative Humidity | Relative humidity recorded at the center of the well in an unoccupied courtroom |
| Distance | Length and width dimensions of the courtroom and courtroom well |

6.1.3.1 Temperature and relative humidity

Temperature recorded at the center of the well in an unoccupied courtroom is considered as temperature in this study. Temperature, as a factor influencing thermal conditions and, hence, performance, has been highlighted in many studies. However, most of those studies describe the influence of temperature in extreme conditions. Generally, courtroom temperature is maintained within a relatively small range, and is not allowed to vacillate towards the extremes. Nevertheless, considering that users generally complain about thermal comfort, temperature was recorded in every courtroom using an EXTECH Instrument's Temperature/Humidity meter (figure 6.5). Relative humidity was also measured in each courtroom, since humidity and temperature determine thermal comfort conditions.



Figure 6.5: EXTECH Instrument's Temperature/Humidity meter.

6.1.3.2 Distance between people in the well area

Length and width dimensions of the courtroom and courtroom well are considered as surrogate measures for distance in this study. Distance has been shown to be an important factor for visual as well as auditory tasks. Logistics did not permit measuring exact distance between each and every pair of location in the courtroom. It is however evident that distances between elements in courtrooms are influenced by the courtroom and well dimensions. Such dimensions are used as proxy measures in the absence of actual data.

6.1.3.3 Variable not considered in this study

Air changes have not been the focus of earlier studies, but have been hypothesized to influence thermal comfort, along with temperature and humidity. This factor was not included owing to lack of appropriate instruments for measurement.

6.1.4 Physical data types

Physical data types pertain to the shapes, sizes and occupancy of the courtroom spaces and courtroom elements. The understanding of courtroom tasks and functions obtained through observation and interviews, described earlier, determined the data types collected on courtrooms. Courtroom spaces considered for the study includes the well area, the spectator gallery, and demarcated public waiting spaces for each courtroom. Elements within courtrooms that were measured include the bench, the court reporter's station, station for the courtroom deputy/clerk, security station (if provided), and the attorney tables.

All length measurements were conducted with the use of Leica Geosystem's DISTOTM pro⁴a (figure 6.6) and a conventional steel measuring tape. Occupancy of spaces was obtained by counting the number of chairs. In case of bench-type seating, the lengths of benches were measured using either of the two instruments. The measurement obtained was divided into equal seating space of 18 inches per person. Eighteen inches is the standard established by the U.S. Courts Design Guide (AOUSC, 1998), and was adopted to maintain uniformity across measurements.



Figure 6.6: Leica Geosystem's DISTOTM pro⁴a.

For courtrooms that are not standard cubes in shape (and courtroom spaces that are not standard rectangles or squares), the plan of the courtroom was sketched on the data recording protocol, and exact horizontal and vertical dimensions were recorded. The following sections outline the measurements that were taken at the courtroom, courtroom spaces, and element levels.

6.1.4.1 Courtroom

Courtroom dimensions measured include:

- Courtroom length(s)
- Courtroom width(s)
- Courtroom height(s)

6.1.4.2 Courtroom spaces

Courtroom spaces include the well area, spectator gallery area, and public waiting areas.

The types of data collected for each area includes:

- Length(s) of space
- Width(s) of space
- Occupancy (number of occupiable seats in the space)

6.1.4.3 Courtroom elements

Courtroom elements on which physical data was obtained include the bench, reporter's station, deputy/clerk's station, security officer's station (if provided), and the attorney tables. For each of those elements the following data were collected:

- Workstation length
- Workstation depth
- Work surface height
- Floor elevation above well (for bench and first row of the jury box)
- Amount and type of storage space provided (linear measurement of each type of storage)
- Edge lip height above well (only for the bench)

6.1.5 User data types

As opposed to the environmental and physical data types, which were collected through a data collection protocol, user and evaluation data types were collected through a survey questionnaire. Several user characteristics have been reported in literature to moderate the association between the environment and performance, preference or other behavior types. The following sections list the data types collected through the questionnaire survey.

6.1.5.1 User age

Age has been shown to be a factor in task performance in the visual as well as auditory domain. Very accurate measurement of age was not warranted and users were requested to report their age as on their last birthday.

6.1.5.2 User gender

Like age, gender has also been shown to be a potential moderator in many studies, and hence included in the study. Users were requested to report their gender on the questionnaire.

6.1.5.3 User role/ position

Five types of users are targeted in this study: 1) judge, 2) courtroom deputy/ clerk of court, 3) court reporter, 4) government attorney, 5) security officer. User role, as a variable in this study, is principally used as a moderator related to task types. It has been asserted in some literature that characteristics of task (level of complexity, multitasking, etc) moderate the association between environmental variables and task performance. In a courtroom setting it could be argued that the task performed by reporters, attorneys and security personnel are considerably different from the other users of courtroom. In view of such an argument, user role (or position) was included as a data type in the survey questionnaire.

6.1.5.4 Vision and hearing deficiencies

Finally, it was assumed that deficiency in vision or hearing might influence the way environments are rated. Lighting and acoustics literature include such variables in many studies (chapter 5). The users were requested to provide information on whether they use any kind of vision or hearing aid while performing tasks in a courtroom, and if so, the type of aid they use.

6.1.6 Evaluation data types

Survey questions included five types of questions depending on which aspect of the work environment was being evaluated. The objective was to get an evaluation from the users about the extent to which the environment is supportive for the tasks they perform. This is different from satisfaction or productivity. As discussed earlier, there are few studies that demonstrate an association between satisfaction and productivity, although they appear to be related in many ways. The supportiveness of a setting to the key tasks performed in the setting is assumed to influence the user's satisfaction with the workplace, which, in turn, influences job satisfaction. Job satisfaction could be asserted as one of the factors influencing productivity in workplace. Similarly, there could be numerous other cultural, personal and other variables that influence workplace satisfaction and job satisfaction. Within such a theoretical framework, that drove the questionnaire development an overall satisfaction question was included to see if any association could be established between a setting's supportiveness to task performance and user's satisfaction with their environment.

Evaluation questions on the physical factors principally included questions on adequacy. Such questions include the adequacy of size, shape, and occupancy to perform certain courtroom functions. Questions on visual performance were mainly regarding the efficiency achieved owing to environmental factors. The same is true for auditory tasks in relation to audibility, clarity and privacy.

Two categories of questions were initially included in the survey but subsequently eliminated from the questionnaire. The first category of question relates to the degree of stress caused owing to environmental factors in the visual and auditory domains. The second category of questions relates to the user's evaluation of the element locations in the courtroom. Two factors led to the subsequent elimination of those questions. One was the length of the questionnaire. There was a constant endeavor to limit the questionnaire to an acceptable length so that all questions could be answered within 10 to 15 minutes. The second reason (more relevant to element location) was to limit categorical variables in the study. A large volume of data was not expected to be collected, considering that the investigator was the sole data collector. Unlike questionnaire survey by mail, telephone or other media, this study involved site visits to each courtroom for the collection of physical and environmental data. There was, thus, a limit to the number of courtrooms that could be visited. Categorical variables increase the number of parameters that need to be estimated. Owing to these considerations, questions on stress and element location were eliminated from the survey. It is assumed, however, that in case of a survey administered through a regular, departmental POE, the length of the questionnaires could be increased to include questions on stress, element location, and other issues.

6.2 Data collection instruments

Lighting, acoustical and temperature/humidity measuring devices used for the study has already been covered in the previous section. This section includes discussions on the questionnaire survey and the data collection protocol. The questionnaire used for the

survey is included in Appendix III, section 3.1, and the data collection protocol in Appendix III, section 3.2. The following discussions start with issues related to the survey questionnaire.

6.2.1 Survey questionnaire

The final version of the questionnaire included six sections of questions on three double-sided A-4 size papers. All measurements are made on a 7-point ordinal scale with descriptive labels attached to each point in the scale. The first page of the questionnaire includes an explanation of the purpose of the study, the way the data would be used, and the rights of the respondents. Issues relating to the supportiveness of the setting were broadly divided into three categories: i) layout, ii) task performance, and iii) other miscellaneous issues (table 6.4 below lists the questions asked in the survey; see Appendix III for the actual questionnaire used). Inquiries on the layout are, as discussed earlier, mainly related to adequacy of size and/or capacity (for carrying out courtroom tasks/functions). Task issues are further categorized into tasks performed in the i) visual environment, and ii) auditory environment. For tasks in the visual environment, questions relate mainly to the adequacy of environmental support to perform the tasks. Inquiries in the auditory environment also relate to adequacy of support to perform speech and hearing tasks, and the ability to obtain privacy when required.

The section on other topics essentially groups all questions that do not fall neatly into one of the above categories. Such topics include sightline obstruction, thermal condition,

color, the overall geometry, and the overall satisfaction of users with their setting. All user demographic questions are included in the fifth section. The sixth and final section provides space for any comments that the user might wish to add at the end of the survey.

Questionnaire design is a relatively complex task that involves several threats to reliability and validity. Steps taken towards assuring the robustness of the questionnaire are addressed in appendix V. Discussions include concerns on questionnaire design outlined in methodological literature, and steps taken in this study to address such issues. The discussions are in four sections: 1) format, 2) question design, 3) testing for reliability, 4) testing for data validity.

6.2.2 Data collection protocol

A protocol for recording physical and environmental data on site was developed for easy and consistent recording of data. Sections in the protocol were created to match the instrument used for collecting data. Such a step ensured that the instruments used for data collection were used only once on each site. The protocol is included in Appendix III.

Table 6.4: POE survey questions.

| Survey section | Questions |
|----------------|--|
| Layout | Well size (jury selection; multi-defendant trial; presenting to jury..): WELL |
| Performance | SIZE, for efficient conduct of courtroom proceedings, is: |
| | Well Shape (jury selection; multi-defendant trial; presenting to jury..): WELL |
| | SHAPE for efficient conduct of courtroom proceedings, is: |
| | Gallery capacity (jury selection; attorney/witness waiting..): GALLERY |
| | SEATING CAPACITY for efficient conduct of courtroom proceedings, is: |

Table 6.4 (continued)

| Survey section | Questions |
|----------------|---|
| | Jury box tiers (hearing, multi-defendant trial.): NUMBER OF TIERS IN JURY BOX, for efficient conduct of courtroom proceedings, is: |
| | Size of public waiting (jury selection; attorney/witness waiting.): SIZE OF PUBLIC WAITING AREA, to reduce disturbance during courtroom proceedings, is: |
| | Seating capacity in public waiting (jury selection; attorney/witness/defendant waiting): SEATING CAPACITY IN PUBLIC WAITING AREA, for efficient conduct of courtroom proceedings, is: |
| | Available work surface (during pretrial hearing, jury selection, hearing, multi-defendant trial, sentencing.): WORK SURFACE to conduct your regular tasks, is: |
| | Storage space: BUILT-IN STORAGE SPACE provided in your work station, to conduct your regular tasks, is: |
| Visual Tasks | Reading from printed documents – including legal documents: Conditions for performing READING TASKS in your courtroom are: |
| | Reading from computer monitors: Conditions for READING/SEEING FROM COMPUTER MONITORS in your courtroom are: |
| | Taking notes, filling forms, cataloging evidence, using computer keyboard: Visual conditions for WRITING/TYPING TASKS in your courtroom are: |
| | Examining evidence: Conditions in your courtroom for VISUAL INSPECTION OF EVIDENCE are: |
| | Faces in Well - judge, deputy, reporter, jury, attorney, witness: Conditions to clearly SEE FACES/FACIAL EXPRESIONS in the Well area are: |
| | Faces in Gallery - potential jurors, attorneys, witnesses, defendants: Conditions to clearly SEE FACES/FACIAL EXPRESIONS of people in gallery are: |
| Auditory Tasks | Speech of people within the Well area; examining deposition evidence; listening to video presentation: From your position(s) of work in the courtroom, the LOUDNESS OF SPEECH from the Well is: |
| | Understanding speech in Well; deposition evidence; video presentation: From your position(s) of work in the courtroom, the CLARITY OF SPEECH from the Well is: |
| | When people in the Gallery speak; e.g jury selection: From your position(s) of work in the courtroom, the LOUDNESS OF SPEECH from the Gallery is: |
| | Ability to clearly understand speech from the Gallery; e.g. jury selection): From your position(s) of work in the courtroom, the CLARITY OF SPEECH from the Gallery is: |
| | Overhearing other's private discussion/conference: From your position(s) in the courtroom, the PRIVACY OF OTHER'S CONVERSATION is: |
| | Your assessment that others cannot hear you when you are discussing/conferring: From your position(s) in the courtroom, the PRIVACY OF YOUR CONVERSATION is: |
| | MOVEMENT OF PEOPLE in Gallery in/ out of the court when courtroom is in session is: |

Table 6.4 (continued)

| Survey section | Questions |
|----------------|--|
| Other topics | SIGHTLINE OBSTRUCTIONS arising from courtroom elements (furniture, equipment) and people are: |
| | The THERMAL CONDITIONS in your courtroom are: |
| | In general the ENVIRONMENT IN YOUR COURTROOM during typical courtroom sessions leaves you: |
| | COLOR OF LIGHT in your courtroom, to symbolize the dignity of law and importance of the justice system, is: |
| | PHYSICAL FEATURES of your courtroom, to symbolize the dignity of law and importance of the justice system, are: |
| | On the whole, considering all aspects of your courtroom (including those not included in this questionnaire) you would rate your courtroom as: |

6.3 Sample

The focus of this study has been on trial courtrooms. Several factors influenced the process of selecting and collecting data from courtrooms. First, in a post 9/11 high security scenarios, access to courtrooms and users has become increasingly difficult. Second, the study involved only one investigator, putting a limit to the number of places that could be visited, and the time spent on the study. Third, the study was not funded, thus, placing a limit to the funds that could be spent. All of these factors (principally the first one) excluded any possibility of probability sampling. The sample used for this study could be described as a combination of “resulting from available subjects” and “purposive sampling” (Babbie, 1998, p.194-195). Babbie points out one major problem with this approach, that of limited generality (for theoretical research). Such issues are discussed in the concluding chapters. The subsequent section elaborates on the sampling process.

6.3.1 Selecting courtrooms

The courtrooms selected for this study depended entirely on the willingness of the administrator/chief judge of a particular courthouse to participate in the study. The federal courthouses that were targeted include the ones that were scheduled for visit as part of a separate funded project in the College of Architecture at Georgia Institute of Technology. The users of those courthouses were informed about the study and requested for participation. In the case of Superior Courts in the state of Georgia, the investigator contacted the Administrative Office (AO) of Georgia Courts. A description of the study was sent to Georgia Courts. The AO of Georgia Courts subsequently forwarded the letter to the administrators of Superior Courts of all judicial districts in the state of Georgia. Interested administrators of judicial district and interested judges responded through telephone calls and electronic mails to the investigator about their willingness to participate. Subsequently, the investigator, to set up a date and time for site visit, contacted the clerk of court or the senior judge in each courthouse. All site visits and measurements were conducted between August 18, 2003 and October 31, 2003. A total of 31 federal and state courtrooms were visited and measured during this period. The following table lists all the courthouses and courtrooms that were part of the site visit.

Table 6.5: List of courtrooms visited for the study.

| Jurisdiction | Judicial District | Courthouse Name | City/ State | Courtrooms Visited |
|--------------|------------------------------------|-----------------------------------|-------------------|--|
| Federal | Northern Ohio | Carl B. Stokes Federal Courthouse | Cleveland, OH | District Special Proceedings Courtroom |
| | | | | District Regular Courtroom |
| | | | | Magistrate Judge Courtroom |
| Federal | Northern Indiana | United States Courthouse | Hammond, IN | District Special Proceedings Courtroom |
| | | | | District Regular Courtroom |
| | | | | Magistrate Judge Courtroom |
| State | 8 th Judicial District | Baldwin County Courthouse | Milledgeville, GA | Superior Courtroom - 2 |
| | | | | Superior Courtroom - 3 |
| State | 9 th Judicial District | Forsyth County Courthouse | Cumming, GA | Superior Courtroom -1 |
| | | | | Superior Courtroom -2 |
| | | | | Superior Courtroom - 2A |
| State | 9 th Judicial District | Pickens County Courthouse | Jasper, GA | Superior Courtroom -(Main) |
| | | | | Superior Courtroom - (Annex) |
| State | 6 th Judicial District | Clayton County Courthouse | Jonesboro, GA | Superior Courtroom - 401 |
| | | | | Superior Courtroom - 405 |
| State | 6 th Judicial District | Fayette County Courthouse | Fayetteville, GA | Superior Courtroom |
| State | 6 th Judicial District | Spalding County Courthouse | Griffin, GA | Superior Courtroom - 1 |
| | | | | Superior Courtroom - 2 |
| State | 6 th Judicial District | Henry County Courthouse | Mc Donough, GA | Superior Courtroom - A |
| | | | | Superior Courtroom - C |
| State | 8 th Judicial District | Greene County Courthouse | Greensboro, GA | Superior Courtroom |
| State | 8 th Judicial District | Putnam County Courthouse | Eatonton, GA | Superior Courtroom |
| State | 8 th Judicial District | Hancock County Courthouse | Sparta, GA | Superior Courtroom |
| State | 10 th Judicial District | Walton County Courthouse | Monroe, GA | Superior Courtroom -(Civil) |
| | | | | Superior Courtroom - (Criminal) |

Table 6.5 (continued)

| Jurisdiction | Judicial District | Courthouse Name | City/ State | Courtrooms Visited |
|---------------------|------------------------------------|--------------------------|--------------------|--|
| State | 10 th Judicial District | Oconee County Courthouse | Watskinville, GA | Superior Courtroom - 1 |
| State | 10 th Judicial District | Clarke County Courthouse | Athens, GA | Superior Courtroom - 2 Superior Courtroom - 3 |
| State | 10 th Judicial District | Newton County Courthouse | Covington, GA | Superior Courtroom - 2 Superior Courtroom - 3 |

6.3.2 Questionnaire response

Questionnaires were distributed to users during site visits along with self-addressed envelopes for mailing to Georgia Institute of Technology. In all, 93 questionnaires were received from users of 26 courtrooms by the end of December 2003, amounting to a response rate of 60%. The following table lists the returned questionnaire by user type. The courtrooms, from which questionnaires were received, vary considerably in physical features. The courtroom areas range between 1077 and 3141 SqFt. The heights of the courtrooms vary from 9 feet to 28 feet. Areas of courtroom well vary between 597 and 2207 Sq Ft. Similarly, seating capacities in public gallery range between 31 seats and 278 seats. Figure 6.7 provides a visual comparison of the 26 courtrooms included in the building model and data analysis described in subsequent chapters. Descriptive statistics of courtrooms are included in Appendix VI.

Table 6.6: Number of returned questionnaires from each type of user.

| User Type | Number of Returned Questionnaire |
|--------------------|----------------------------------|
| Judge | 24 |
| Court deputy/clerk | 26 |
| Court Reporter | 19 |
| District Attorney | 18 |
| Court Security | 6 |
| Total | 93 |

This chapter outlined the major variables included in the study, and their operational definitions. The next major step involved developing a conceptual model, integrating as-built and POE data. Issues related to modeling and database developments are discussed in the chapter 7.

6.4 Summary

Variables included in this study include task illuminance, task brightness, background brightness, surrounding brightness, glare (surrogate measure), light direction, spectral distribution (surrogate measure), screen illuminance, screen luminance, sightline obstruction, reverberation time, background noise, movement noise, temperature, relative humidity, distance between people in the well area (surrogate measure), courtroom dimensions, dimensions of courtroom spaces, dimensions of courtroom elements, user age, user gender, user role/ position, and vision and hearing deficiencies.

The physical and environmental variables were measured with commercially available instruments. User and evaluation data were measured using a survey questionnaire.

A total of 31 state and federal trial courtrooms, in 16 courthouses, were visited during the POE studies conducted in fall 2003. Ninety three surveys were received from users in 26 courtrooms, amounting to a response rate of 60%.

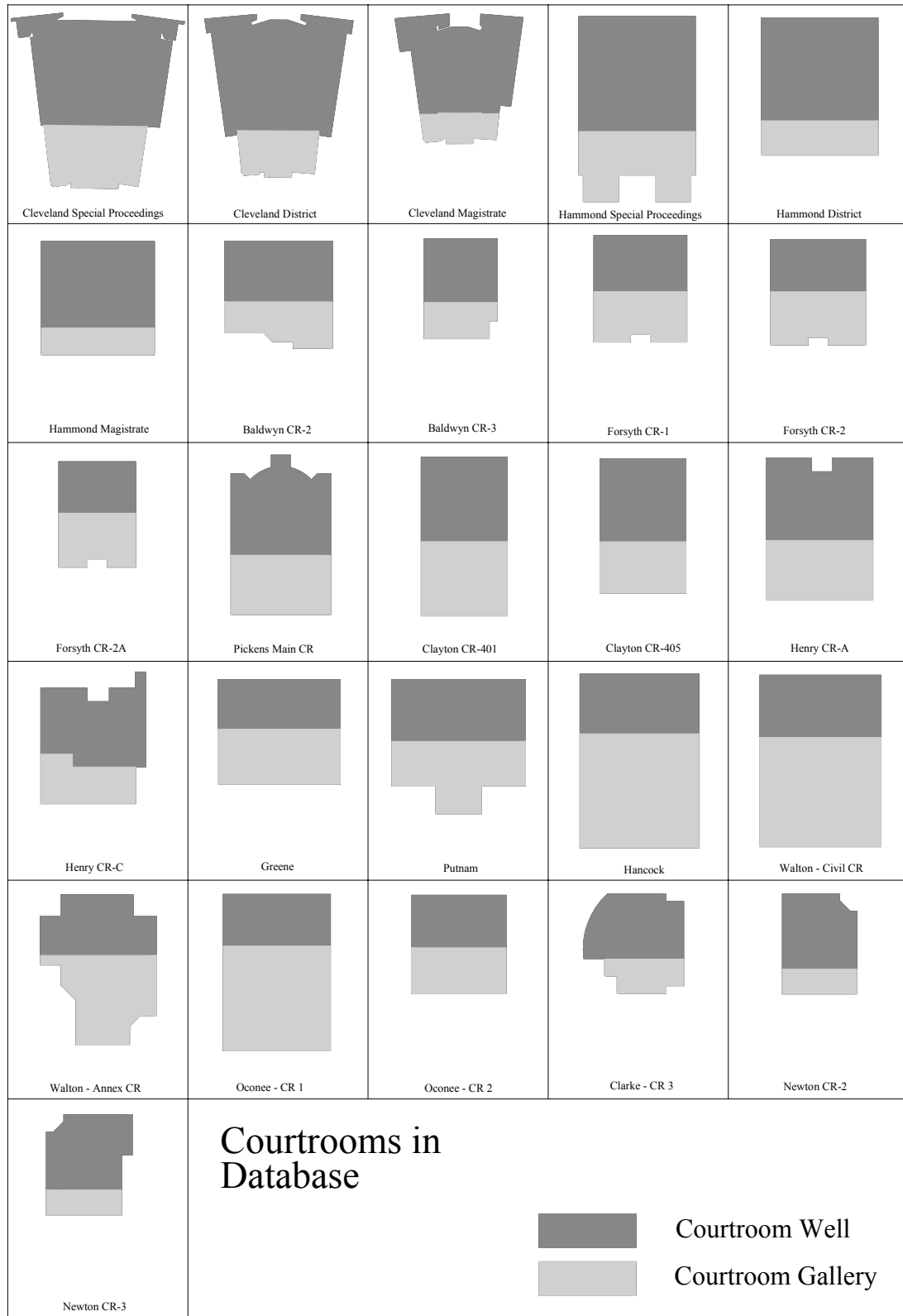


Figure 6.7: Plans of courtrooms included in the building data model.

Chapter 7

The Building Model

The previous chapter outlined the list of data collected during the POEs of courtrooms. The purpose of this chapter is to describe the data model developed in this study. Data modeling is not a new domain. The uniqueness of the model developed here lies in the integration of evaluation data with as-built data of courtrooms, with the objective of interfacing design decision-making and evaluation data. Before describing the data model a brief sketch of conceptual modeling, and the language used for the modeling effort is warranted. The chapter includes:

7.1 Conceptual modeling

7.2 The EXPRESS language and its applications

7.3 The model

7.3.1 Site, building, and floor

7.3.2 The enclosure system

7.3.2.1 Wall

7.3.2.2 Horizontal separators

7.3.3 Functional clusters

7.3.3.1 Use space and space zone

7.3.3.2 Courtroom elements

7.3.3.3 Movables

7.3.4 User and POE data

7.4 Database

7.5 Summary

7.1 Conceptual modeling

Collecting data and storing for future use has been a constant pursuit. Broadly speaking, the objective behind storing data is to retrieve appropriate/ pertinent data when needed. This objective is not served if the data retrieved is not related to the issue at hand. The objective is also not properly served if huge volumes of unnecessary data accompany the needed data during retrieval. There exist complex relationships between data types. When the complexity of data being handled is low, simple storage mediums could serve suitably. Such storage mechanisms could include spreadsheets, statistical software packages, or even text software. However, when the complexities of relationships between data types are high, a way to manage the data becomes essential. The principal objective behind such efforts remain the same – to enable easy search and retrieval of appropriate/ pertinent data when needed. Data management strategies assist in, among others, reducing semantic ambiguity between data types, ensuring referential integrity between data, and, more importantly, managing data at very high level.

Conceptual modeling of data provides a foundation for efficient data management. As simple storage of data proves increasingly inefficient, the conceptual modeling approach begins with probing the data set to articulate inherent characteristics of the data, things that the data represent, and the way the various data types are related. Various novel

concepts developed over the past decades have helped accelerate the power of conceptual modeling. One of the pioneering ones was abstraction (Eastman, 1999). Abstraction helps develop a representation in hierarchical fashions where higher order terms in the representation embody the characteristics of all lower order terms, thereby reducing the complexity of the entire representation. A type of abstraction is specialization that articulates inheritance structures among entities. Aggregation is another type of abstraction that enables grouping of data into single entities. Similarly, composition enables representation of objects that are composed of several entities. A major objective of conceptual modeling is to capture the inherent complexities in data characteristics and their relationships in a simplified representation medium. The simplification enables efficient data management.

In this study, the various elements that describe courtrooms, the functions of courtrooms, the users that perform the functions, and evaluations of courtroom as a work setting was probed to identify and articulate the data in a simplified conceptual structure. Many languages are available for developing conceptual models (such as Entity-Relationship models, EXPRESS, etc.). Each language has its own strength in the types of data and relationships that could be represented. EXPRESS is a language already being used to develop comprehensive representations of buildings, and hence the language used in this study.

7.2 The EXPRESS language and its application

The language used for the model illustrated in this chapter is EXPRESS-G. Since data modeling languages, in general, may not be familiar to everyone, a straightforward description of what modeling languages are and a brief history of their development was considered essential. Eastman's (1999) book on building product models provides a more comprehensive, chronological, description of the development and syntax of product modeling languages, and some sections of his descriptions are referenced at appropriate places.

The EXPRESS modeling language was developed as a part of the ISO-STEP (Eastman, 1999) attempt to create standard representations of buildings and building components, with the objective to enable seamless exchange of data between different systems. It was initially developed, during the mid-1980s, in the aerospace industry (Eastman, 1999), and, subsequently, adapted by the building industry for modeling building components and products. The purpose of EXPRESS (quoting Eastman, 1999) “is to represent a product model in an implementation independent manner” (p.146). Over the past decades, the language has been used in large research projects including CIMsteel (see Eastman, 1999), which was developed to improve steel constructions, and COMBINE, a project focusing on building energy efficiency (Augenbroe, 1994; Augenbroe, 1995; Eastman, 1999). In essence, EXPRESS uses entities and relationships between entities to represent systems. The entities could include abstract concepts, a development resulting from object-oriented modeling languages. One or more attributes, attached to each entity,

characterize the properties of the entity. The use of several basic data types, as well as constructors to group data, enables the representation of values of the attributes. Further, a number of rules are available to define constraints, and add richness to the semantics of the model. Inheritance structures constitute one of the basic semantics of the language, which also enable the representation of systems in an economical manner. The entities, relationships and rules, combine to produce schemas that provide a way to construct meaningful representation of systems. Schemas can reside within larger schemas, which allow the creation of nested representations that characterize many real world phenomena, in addition to building systems.

Traditionally, the general modes of building representation have been through CAD drawings and models. CAD models, however, are essentially a collection of lines and points. The problem with such representations is the limited information such models can hold. For instance, while the CAD models could store information on geometry, it promises little more in information content. Development of object-oriented modeling languages provided a platform for exploring richer and more holistic representations of buildings. Those include data on material properties, their longevity, and numerous other data types. The modeling language, in this form, enables engineers to describe building components geometrically (thus providing information on location, form, areas, and volume) as well as in terms of their thermal, lighting, acoustical and other properties. Such a model, which is currently in various phases of development within ISO-STEP, promises to represent a building in its totality, with a large variety of data, which would be accessible over a building's entire lifespan to facility managers, maintenance

personnel, designers, and other users. Various sub-committees in ISO-STEP are currently working on developing a comprehensive and standardized model for representing building product data across systems of practices.

Before the advent of the object-oriented programming and modeling languages, the kind of data that could be handled or modeled was restrictive. A small number of primitive data types were all that was available to human experts to create representation systems that are machine-readable. Most non-physical processes, however, are too complicated to mend themselves to a narrow range of representation types. Most concepts that are studied in EB research, and dealt with in profession, are complex and abstract. The development of object-oriented modeling and programming languages facilitated the definition of abstract entities. That opened up more avenues for people to represent systems, products, and processes that are truer to systems, products and processes encountered in practice.

The premise of this thesis has been that the ISO-STEP model could be expanded to represent an additional layer of data, which, however, are not of the same class as building products –performance of the designed spaces. The model being developed by ISO-STEP will be a repository of an almost complete range of data pertaining to the designed physical environment. The addition of performance data would begin to provide meaningful links between the physical setting and its performance and, thus, provide robust ways of predicting the impact of future designed environments. It would begin to help assess design decisions based on existing evaluation/performance data on similar

buildings or setting types. Post occupancy evaluation methodology provides a means to develop one kind of performance data structure – that of the user’s assessment of their environment. While other types of evaluation/performance data could be explored and added to the list of data types, POEs have some immediate appeal. First, POEs (or FPEs – a more recent term being used is Facility Performance Evaluations) have been already accepted as part of facility management strategy in large government and private organizations. The process, thus, is already established, and needs little more in logistic planning for implementation. Second, it is done regularly in some organizations, which means data collected over time can be stored (accumulating enough critical mass to provide generalizable information), and begin to provide information on trends.

In view of the impediments in current POE practices, articulated in chapter 2, conceptual modeling of POE data offers substantial promise. Schema-based representations of data, which enables nesting, inheritance, aggregation and composition, offer a richer medium for data representation. Courtrooms and evaluation issues can be aggregated and classified meaningfully. Completed relationships (such as multiple user types, in multiple setting types, evaluating multiple issues) could be appropriately represented. Data from multiple POEs can be added without losing comprehensibility of the model. In addition, the semantics behind the data structure can be represented in an explicit manner, thus adding to its communication, and shared representation, capabilities. Finally, it will enable placeholders for data pertaining to both the as-built environment as well as POE, rendering a complete representation of data dealt with in EB research. In essence, the model developed in this dissertation, and described in this chapter, essentially integrates

two very different types of data in a single semantic representation. One aspect of the data structure relates to descriptions of the as-built environment, and the other to evaluation of the as-built setting.

The part of the model describing the setting, in this dissertation, is a simplistic representation of the more comprehensive data structure developed in ISO-STEP. There were two main avenues available while designing this model. One was to use the STEP model as the base and build on top of it. That process would have increased the complexity of the modeling process, and diverted resources to issues not central to this dissertation. The second avenue involved the development of a representation that would capture the essence of the STEP model, and focus more resource on the main question – that of structuring POE data and integrating the two diverse data types. The second avenue was adopted for logistic reasons. Yet another matter deserves clarification before the model is described. The model defined and described in subsequent sections was developed using EXPRESS-G modeling language. EXPRESS-G is the graphic version of EXPRESS. It does not, however, include all the functionalities offered by EXPRESS. For instance, rules can only be defined in EXPRESS, which also enables defining more sophisticated relationships as compared to the graphical version. The use of EXPRESS-G, nevertheless, should be viewed from a larger perspective of the modeling process. Traditionally, the programmers and domain experts worked separately, with the domain experts contributing to the desired utility and functionality, and programmers working on the operational side to build a system that could be run in a computing environment and provide the desired outcomes of a modeling process. Frequently, some form of mediation

was necessary to translate the requirements defined by domain experts to the people engaged on the programming side. The development of a graphic interface (as in EXPRESS-G) results in the possibility that domain experts could begin to design representation systems that could be shared by experts in the computing field. From such a viewpoint, the work described here is better appreciated as one originating primarily from a domain expert, with some knowledge about computing environments.

7.3 The model

The model described here is larger than what is strictly required for this thesis. The purpose of designing a larger model was to enable discussions on possibilities that are beyond the scope of this study, some of which are addressed in the concluding chapter. Owing to the inclusion of some other possible outcomes, certain entities and attributes (exemplary in nature) are included in the model. Some of the elements and attributes included in the model have direct relevance to this study but remained unused since data pertaining to such elements were not available in the post occupancy evaluation conducted as a part of this thesis.

Most building models attempt to describe and represent a designed environment in great detail the objective being to articulate a building in as complete a representation as possible. One subtle difference between those models and the one being described here is that the model in this study is intended to assist focused query and retrieval of pertinent evaluation as well as as-built data to be used in a design or design review phase, as well

as for academic inquiries. The fundamental difference is in the addition of schemas related to functions and evaluations. Figure 7.1 below illustrates the concept behind the current data modeling exercise. Research works on representing building components have made tremendous progress over the past years. The main contribution made through this study is the addition of performance data to the data structure (also worth noting is the fact that traditional POE studies did not include comprehensive data on the as-built environment).

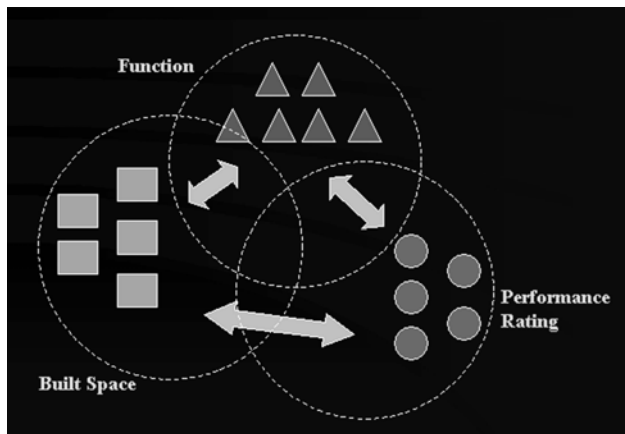


Figure 7.1: The key concept involves the integration of as-built data with functions and performance.

The model can be viewed as four chunks of data structure, linked through the entity ‘space’ – a generic definition for usable spaces bounded by enclosures:

- identifiers that hold data that would enable identification a particular site, project, building, and floor;
- the enclosure system, which includes the walls, floors and ceilings within which functional spaces are housed;

- various functional areas within an enclosure system;
- and, finally, data generated from evaluation studies of the spaces described in the model.

Readers may find the modeling of geometric data incomplete, which was intentional with the objective to reduce the complexity of the model and modeling effort. The following sections describe each portion of the model.

7.3.1 Site, building, and floor

In this model, data on site, building and floor are essentially used as higher level identifiers and classifiers of courtrooms. All attributes of site, building, and floor are designed to assist focused queries. For instance, it is envisaged that an end-user would generally filter data based on jurisdiction (state versus federal), focus on courtrooms in a particular judicial district, or focus on one (or more) courthouse. The schema, however, could be expanded to include more data on the site, context, and buildings in which courtrooms are located.

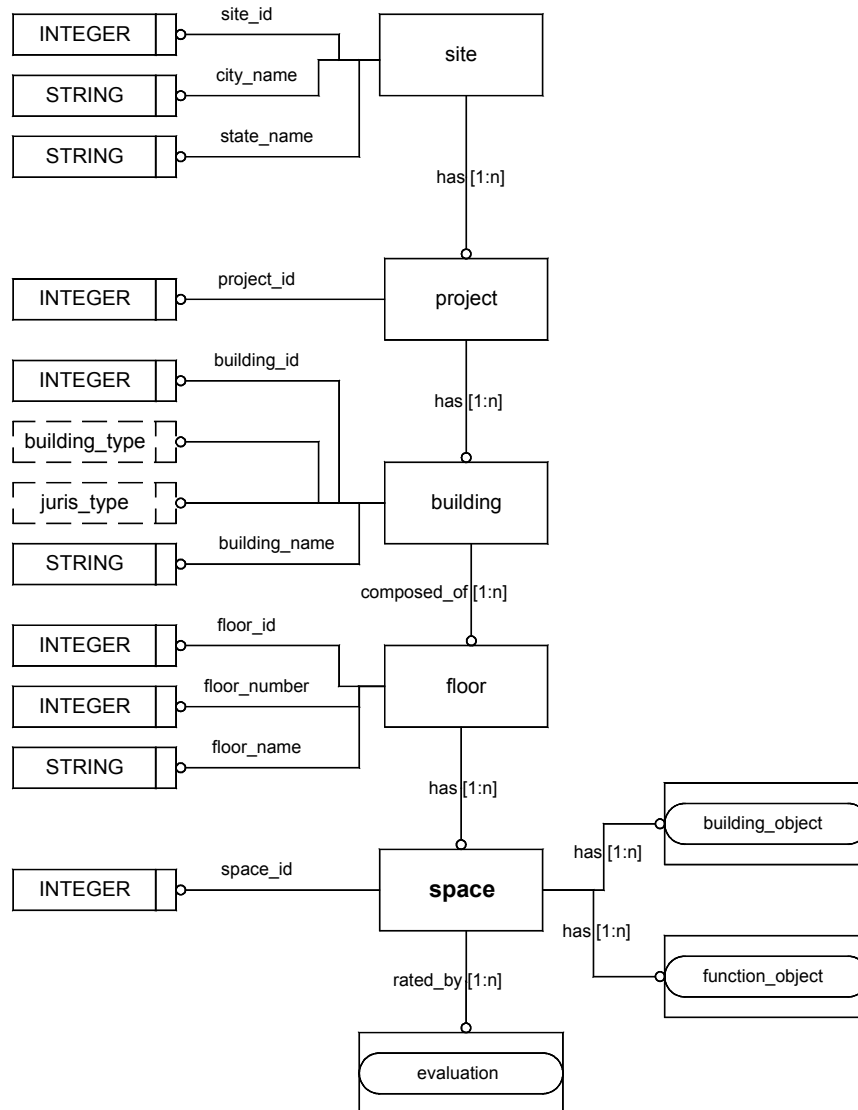


Figure 7.2: Schema representing data on site, building and floor.

Figure 7.2 shows the portion of the model that represents information on site and building. Every *space* or part thereof being evaluated could be associated with a *site*. Attributes of a site include the name of the city (*city_name*) and the name of the state (*state_name*) in which the site is situated. Other attributes, for instance street address and similar data types could be added to the entity *site*. Every site could have one or more

building projects (*project*). The projects could be of the same or different building types. For instance, many courthouse projects are annex buildings where the main (older) courthouse structure shares the same site. Alternately, the same site could hold different building types, as is the case in many central city government districts. Further, each *project* could include one or more buildings of the same or different types. The entity *building* describes the building type. While this study specifically deals with courthouses, the entity was named *building* to allow discussions pertaining to the possible generality of the model to capture evaluation data on other building types. The *building_type* attribute describes the occupancy types of the building, which in this case is a courthouse, and could include offices, schools, embassies, border stations, and other occupancy types. The administrative jurisdiction within which the building falls is described by *juris-type*. Examples of jurisdiction include federal, state, county, and city governments. At the building level, each building can be conceptually divided into different floors (*floor*). The floors typically have floor numbers (*floor_number*) as identifiers. Further, some floors may have a name, such as magistrate courts floor (*floor_name*). Based on the design of the enclosure system and environmental support systems, each floor could be conceived of as having one or more spaces (*space*). The elements and attributes described so far are listed in table 7.1.

Table 7.1: Entities and attributes related to site and building.

| Entity | Description |
|-------------------|--|
| <i>site</i> | Entity that holds site data. For this study <i>city_name</i> and <i>state_name</i> constitute the main attributes. |
| <i>city_name</i> | Name of city in which the site is located. |
| <i>state_name</i> | Name of state in which the site is located. |

Table 7.1 (continues)

| Entity | Description |
|----------------------|---|
| <i>project</i> | Entity that holds data pertaining to the project of interest. Each site could have one or more projects. No project specific attributes are identified in this model. |
| <i>building</i> | Entity that holds data pertaining to a building. Each project could have one or more buildings. Building type (<i>building_type</i>), jurisdiction type (<i>juris_type</i>), and building name (<i>building_name</i>) describe the building in this model. |
| <i>building_type</i> | An enumerated list that identifies the occupancy type of a building, as in courthouse, office, school, embassy, and border station. |
| <i>juris_type</i> | An enumerated list that identifies the administrative jurisdiction under which a building falls, as in federal, state, county, and city government. |
| <i>building_name</i> | The officially assigned name of a building as in Carl B. Stokes Federal Courthouse. |
| <i>floor</i> | An entity that would hold data to identify a floor. Floor number (<i>floor_number</i>) and any name assigned to a floor (<i>floor_name</i>) are the two attributes describing a floor in this model. |
| <i>floor_number</i> | The level of the floor above the assigned ground level in a building, as in floor 11. |
| <i>floor_name</i> | Any name assigned to a particular floor, as in magistrate courts floor. |
| <i>space</i> | A generic description for all kinds of spaces on a floor. Each floor could have many different types of spaces. Space here is physically defined by the design of the enclosure and environmental support system. In courthouses, the courtroom is defined as a space, which has different types of functional zones within it. |

7.3.2 The enclosure system

Schemas on the enclosure system are designed to hold as-built data on elements that physically define (enclose) the courtrooms. Such elements include the walls, floor, ceiling, and the services support systems.

Figure 7.3 illustrates the general enclosure schema that includes schemas of walls, floor and ceiling in this model. Components of the enclosure system and those associated with service systems are described through the entity *boundary_object*. Boundary objects hold

and define a space physically, and provide environmental support. Physical definition is performed by *boundary_element*, which could be *physical* elements (as in case of walls and floors) or *virtual* elements. Virtual elements are elements that separate spaces but are not walls or floors, although this sub-schema is not used in this study. Description of components of environmental support systems is done through *service_element*. Once again, this section of the model is not used in the study, but includes placeholders for schemas on mechanical, electrical, sanitary, communication and information-technology components for possible expansion. The physical boundary elements are conceived of as either *structural* or *non_structural*, and for the purpose of this study (which is focused on courtrooms) only the non-structural boundary elements are used. Components of the non-structural elements that are defined in this model include *wall*, floor (named here as *space_floor* to differentiate it from the entity *floor*), and *ceiling*. The schemas on wall, floor and ceiling are further expanded to hold actual data on as-built environments.

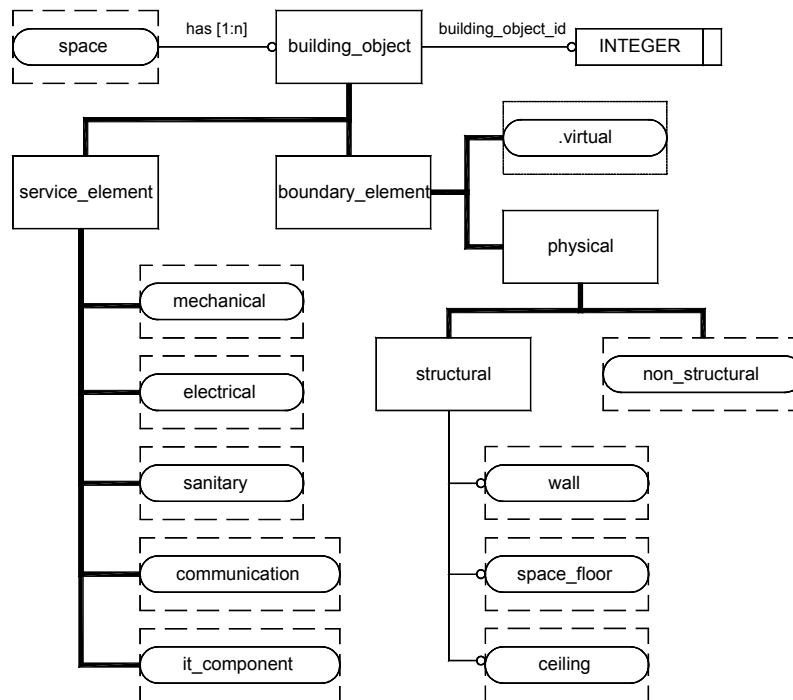


Figure 7.3: The general enclosure schema that includes schemas of wall, floor and ceiling in this model.

7.3.2.1 Wall

The entity *wall* captures data on all separators that physically divide/bound the space of interest on the horizontal plane (see figure 7.4). The attribute *wall_type* may not be relevant to all kinds of spaces. However, in a courtroom, identifiers, in addition to *wall_ids*, helps in comprehending the exact type of wall being described. Wall type in this study has been arbitrarily assigned values such as ‘bench wall’, ‘jury wall’, gallery wall’, etc., which may not be useful in all setting types, but has been introduced with the assumption that it would render wall identification in courtrooms more convenient. Wall

as an entity is shown to have a core *structure*, some type of *cladding* on top of the structure, and none or more openings (*opening*). One attribute of cladding that is being used in this study is the aggregated *luminance* value of the wall. Examples of other possible attributes are also shown. Walls also have none or more openings, which could be either variations of *door* or variations of *window*. Any opening that allows physical passage between two spaces is considered as a door. All other opening types are considered as windows. Although courtrooms have many doors, and characteristics of doors influence courtroom functions in significant ways, data on doors could not be collected during the POE conducted for this study. Nevertheless door and some possible attributes are included in the model. Of particular interest for courtroom operations are attributes like type of door hardware, door design, transmission loss value of the door, and the type of acoustical gasket. Other studies and space types might have different kinds of attributes of interest. Two attributes of windows were recorded during the POE study. One is the *area* of windows in the courtroom, and the second is the luminance value. As discussed previously, additional attributes have been shown for most elements to provide a larger perspective on attribute types, and the expandability of the model across studies as well as building types. The elements and their attributes in the wall schema are outlined in Table 7.2.

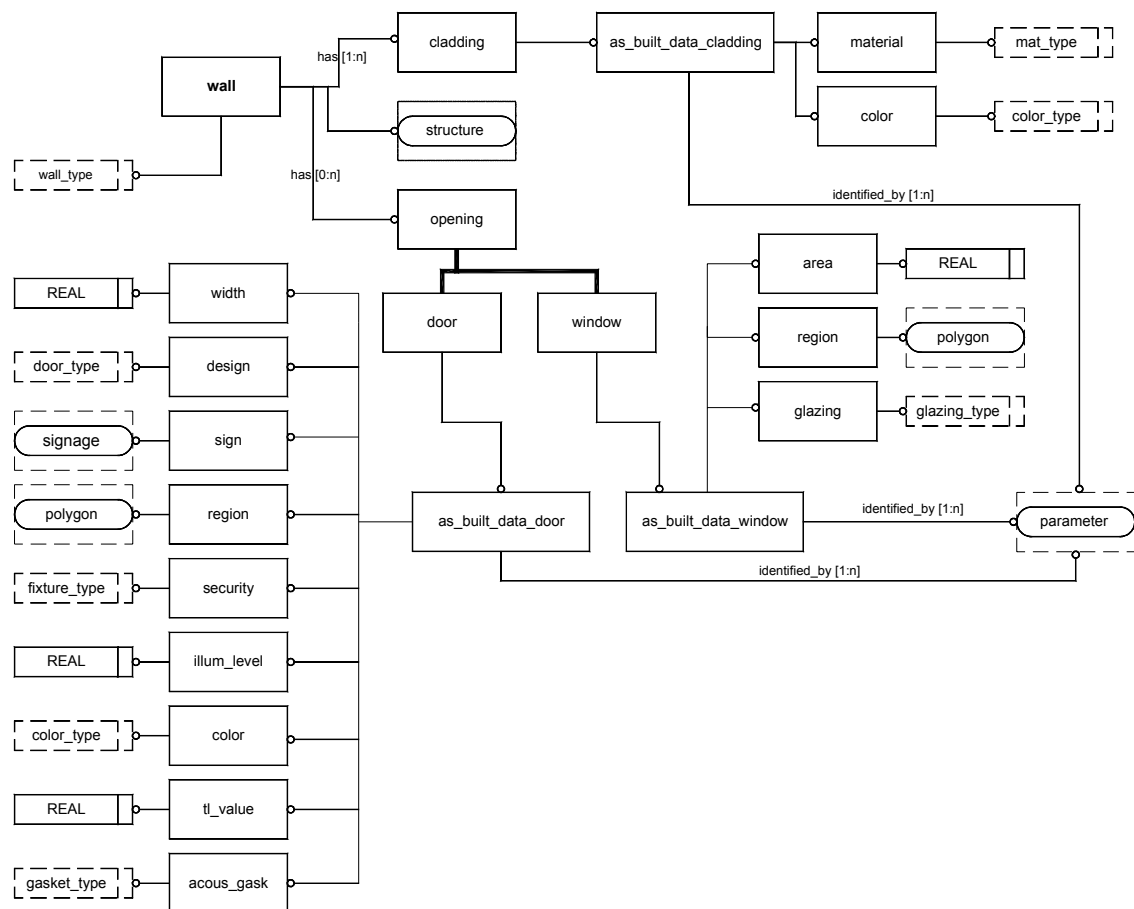


Figure 7.4: Schema showing wall and its attributes.

Table 7.2: Entities and attributes related to wall enclosures.

| Entity | Description |
|------------------|--|
| <i>wall</i> | Physical separators of space on the horizontal plane. |
| <i>wall_type</i> | A meaningful identifier of a wall where available; as in ‘bench wall’ and ‘jury wall’. |
| <i>cladding</i> | Wall cladding, the final finish of the wall surface that is encountered by space users. |
| <i>luminance</i> | Average luminance value of a wall as measured on site. |
| <i>opening</i> | A door or a window that provides physical, visual or some other form of access between two separate spaces. |
| <i>window</i> | A type of opening that does not provide physical access between two separate spaces. |
| <i>area</i> | A type of physical data (in this case pertains to the area of window). In a more detailed model this will be derived from geometry data. |

The entities *as_built_data_door* and *as_built_data_window* in this schema add typological information to the attribute data for every entity of interest. As-built data *parameter* provides the first level of classification structure and data *domain* provides finer level of data identification. These levels, as will also be discussed later, are parallel in structure to the classification of user evaluation data types. Table 7.3 shows the items (including, some exemplary in nature) under each level of data classification. Physical data types could pertain to dimensions of spaces/elements, and seating capacity (or storage capacity), which are the data of interest in this study. It could also be about durability, strength or other types of physical characteristics/property of the as-built space. Environmental data types captured in this study include data pertaining to lighting, acoustical, and thermal environment in courtrooms. Similarly, other data types could also be added to the model, examples being the social environment and financial data, which is of interest in many E-B studies. Figure 7.5 below illustrates the schema on parameters and data domains.

Yet another class of data type could be added to the model (which is not shown in the model but mentioned for discussion sake only) that pertains to designed data. All POE data on the physical and environmental setting are, as the name suggests, as-built data (or data on buildings in use). In contrast, a separate set of data on the same components could be on what was designed, which constitute the data types in most traditional building models. Thus, illuminance level on the bench, for instance, could have two values, one pertaining to the value that was targeted during design, and the other to the actual measured value during an evaluation study. It could be argued that such data could be of

value to designers in the engineering as well as architectural profession. Entities such as *as_built_data_door* and *as_built_data_window* help distinguish POE data values from as designed data values. Table 7.4 outlines the entities and attributes related to data parameters and domains.

Table 7.3: Examples of parameters and domains in as-built data classification.

| Parameter Type | Domain Type |
|------------------|--|
| Physical | Dimension/Capacity <i>Durability</i> <i>Strength</i> |
| Environmental | Lighting Acoustics Thermal |
| <i>Social</i> | ... |
| <i>Financial</i> | ... |

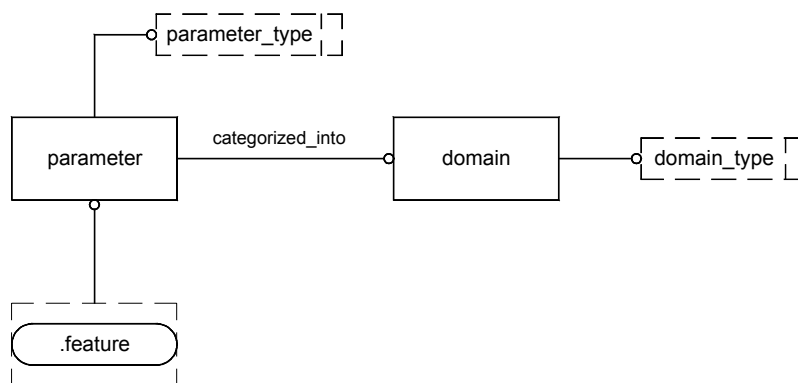


Figure 7.5: Parameters and data domains for classifying as-built data.

Table 7.4: Parameters and domains in as-built data classification.

| Entity | Description |
|-------------------------|---|
| <i>as_built_data_()</i> | Data types that relate to measurements performed in buildings-in-use (as in the case of POEs). It is different from as-designed data – data types related to target values considered during design phases. |
| <i>parameter</i> | A classifier of as-built data to assist in focused search and query; as in ‘physical’, ‘environmental’, ‘social’, etc. |
| <i>domain</i> | A finer identifier of data types within each parameter of as-built data; as in lighting, acoustics, dimensions/capacity, etc. |

7.3.2.2 Horizontal separators

A second component of non-structural boundary elements are the floors (*space_floor*). Floors are defined as the base boundary element on which all activities in a space are performed. While many types of attributes could be assigned to the floor (figure 7.6), the only data collected in this study is the floor *luminance*. The same is true for the entity *ceiling*. The ceiling (figure 7.7) has been shown to have a framing system (*frame*), one or more panels (*panel*), and none or more fixtures (*fixture*). The average *luminance* value of the panel is the only attribute data captured in this study. As discussed previously detailed data on geometry was not built into the model, intentionally, and the actual geometry data of interest is directly attached as attribute to the elements associated with function objects. Table 7.5 outlines the key entities and attributes related to floor and ceiling.

Table 7.5: Floor, ceiling and attributes.

| Entity | Description |
|--------------------|---|
| <i>space_floor</i> | A physical boundary element that acts as a base on which various activities are performed in a space. |
| <i>luminance</i> | An as-built data type, pertaining to luminance value measured on site. In this case of the floor or ceiling of the courtroom. |
| <i>ceiling</i> | The upper boundary element of a space. |
| <i>panel</i> | Finishing components of a ceiling that is encountered by users of a space. |

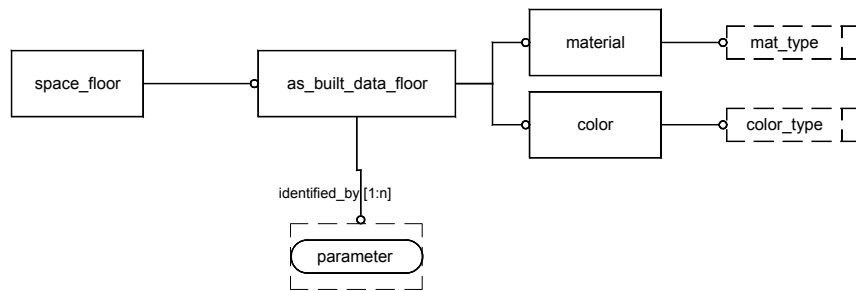


Figure 7.6: The floor schema.

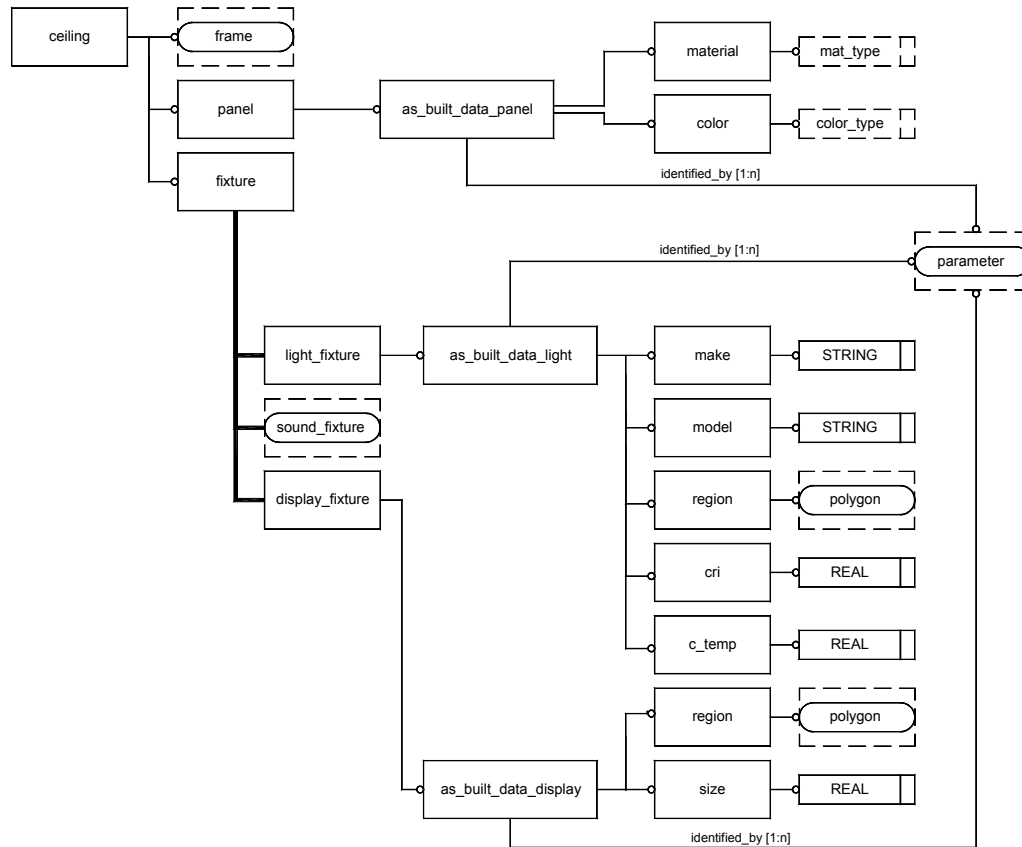


Figure 7.7: The ceiling schema.

7.3.3 Functional clusters

Functional clusters hold data on functions and sub-functions on the spaces physically defined by the enclosure systems. At higher level descriptions, the data consist of space typologies. At each subsequent level of decomposition, the nature of function is further articulated. The schema captures the major (higher level) functions, various sub-functions or functional zones that organizationally cluster together to define a functional unit, key elements within the functional zones, and the movables (furniture and equipments) that aggregate to describe the key elements. Relationships of interest between each pair of

movables are included, such as the distance between elements or the level difference.

Such relationships are of design and research interest not only in courtrooms but also in most work settings.

The spaces as defined by the boundary elements described above play host to various types of functions. In some cases the function in a space could be singular, whereas in other cases a space could be associated with multiple functions. Each function type is described as a *function_object*. For simplicity sake, the *function_object* types have been defined as *use_space*, *circulation_space*, and *utility_space* (figure 7.8), while it is appreciated that various combinations of these function types are also possible. Use space is considered as the space where the primary task is performed. Circulation space is considered as including spaces that are set aside for circulation between various function object types. Utility space is considered as including spaces set aside for utilities. For the purpose of this study the primary function of a space is considered for function type assignment. Also, only use space is considered since only courtrooms and public waiting areas are covered in the POE study.

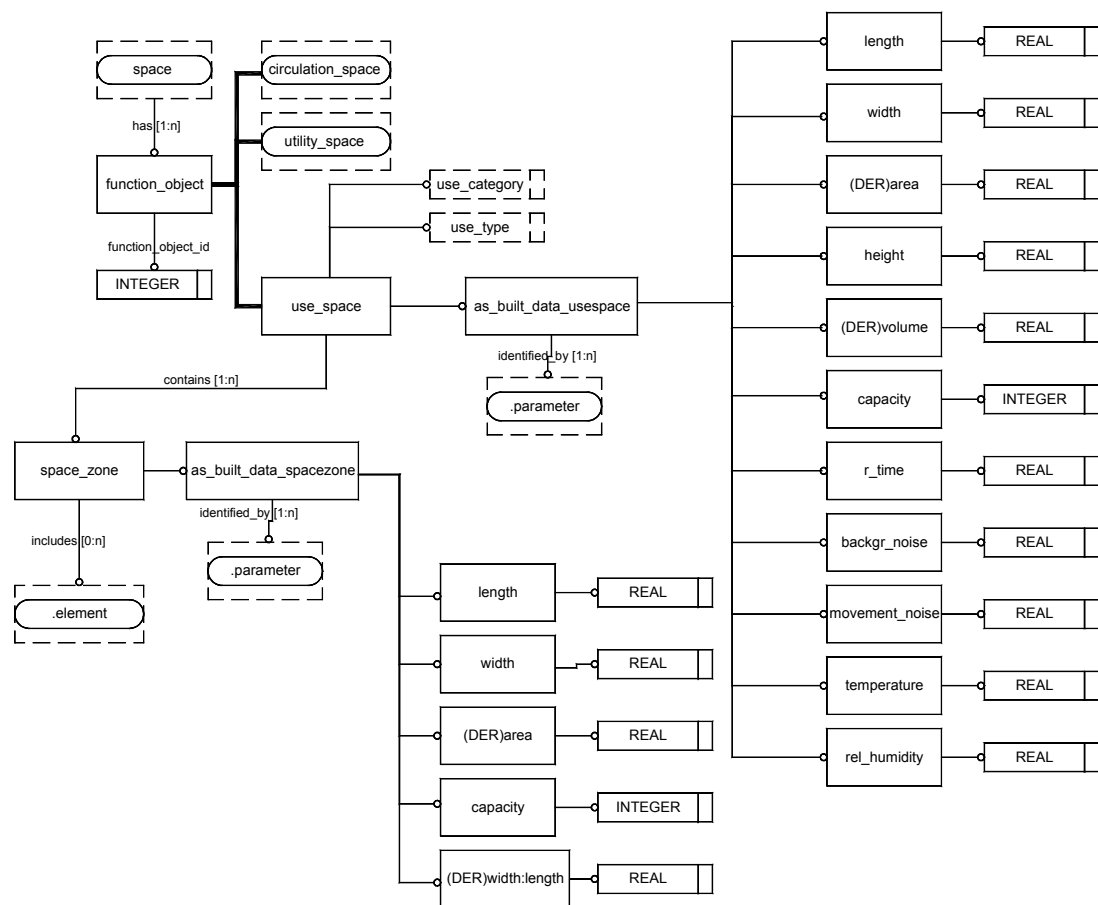


Figure 7.8: Use space and space zone as function entities.

7.3.3.1 Use space and space zone

Each use space is identified by a *use_category* and a *use_type*. Use category refers to the primary function of the use space, as in ‘courtroom’. Use type provides further information by stating the particular subtype of the primary function, as in ‘magistrate judge’ (courtroom). Each use space could be host to one or more space zones (*space_zone*). These are secondary level of functions carried within a larger function

type. In a courtroom, for instance, two space zones are defined: the courtroom well, and the gallery (or spectator seating area). These two zones have different secondary functions (although within the general function of a courtroom), and are typically separated through symbolic barriers. Each use space and space zone have certain attributes that are captured during POE studies, and that could be (or are) of interest to designers and researchers. Such attributes include physical data pertaining to *length*, *width* and *height*, as well as derived attributes on *area*, *volume*, and *width:length* ratio (that provides some objective information on the shape of the space). Seating *capacity* is yet another attribute of interest. Environmental data, pertaining to use space and space zone, that are captured in this study include the reverberation time (*r_time*), ambient/background noise level (*backgr_noise*), noise from movement in the gallery (*movement_noise*), *temperature*, and relative humidity (*rel_humidity*). Table 7.6 outlines the entities and their attributed related to use space and space zone.

Table 7.6: Entities and attributes related to use space and space zone.

| Entity | Description |
|------------------------|---|
| <i>function_object</i> | Area occupied by a particular function type within a bounded space. |
| <i>use_space</i> | A type of function object where the main task of an organization is performed. |
| <i>use_category</i> | An identifier of a use space type; as in courtroom. |
| <i>use_type</i> | As identifier of the type of use category; as in ‘magistrate judge’ courtroom. |
| <i>space_zone</i> | Zones within a use space where sub-tasks are performed within the umbrella of the main task of a use space. |
| <i>length</i> | A type of as-built physical data; as in length of a courtroom or a courtroom well. |
| <i>width</i> | A type of as-built physical data; as in width of a courtroom or a courtroom well. |
| <i>area</i> | A type of derived as-built physical data; as in area of a courtroom or courtroom well. |
| <i>capacity</i> | The seating capacity of a use space; as in the total capacity of a courtroom or a public waiting area. |

Table 7.6 (continued)

| Entity | Description |
|-----------------------|--|
| <i>width:length</i> | A type of derived as-built physical data; as in width:length ratio of a courtroom or courtroom well. |
| <i>height</i> | A type of as-built physical data; as in height of a courtroom. |
| <i>volume</i> | A type of derived as-built physical data; as in volume of a courtroom. |
| <i>r_time</i> | Short for reverberation time. A type of environmental data in the acoustical domain; as in the reverberation time measured in a courtroom. |
| <i>backgr_noise</i> | Short for ambient/background noise. A type of environmental data in the acoustical domain; as in the background noise measured in a courtroom. |
| <i>movement_noise</i> | A type of environmental data in the acoustical domain; as in the movement noise arising from the spectator gallery measured in a courtroom. |
| <i>temperature</i> | A type of environmental data in the thermal domain; as in the temperature measured in a courtroom. |
| <i>rel_humidity</i> | Short for relative humidity. A type of environmental data in the thermal domain; as in the relative humidity measured in a courtroom. |

7.3.3.2 Courtroom elements

Within each space zone there could be none or more elements (*element*). Elements are specialized units within a space zone that perform very specific functions. In a courtroom well, the elements included in this study are the bench, the reporter station, the deputy/clerk's station, the security personnel station, the attorney area, and the jury box. Witness stand, which is not included in this study, is also an element within the space zone called courtroom well. Other space zones, as in the case of the gallery, will have only one element, i.e. the spectator seats. The attribute *element_type* acts as the holder of the list of elements. While numerous attributes of interest can be listed, the only data collected in this study, pertaining to courtroom elements, relates to the number of rows in the jury box (the same attribute also holds true for the gallery seating area) and seating capacity in the gallery. Other physical attributes can also be derived and associated with

each element. Figure 7.9 illustrates the element schema, and table 7.7 lists the entities and attributes associated with the element schema.

Table 7.7: Elements and attributes associated with courtroom elements.

| Entity | Description |
|---------------------|---|
| <i>element</i> | Zones of specialized function within a space zone. |
| <i>element_type</i> | A typology structure that provides identity to an element; as in bench, jury box, witness stand, etc. |
| <i>#_of_rows</i> | Short for number of rows. A type of as-built physical data; as in the number of row in the jury box. |
| <i>capacity</i> | A type of as-built physical data; as in the seating capacity in the spectator gallery. |

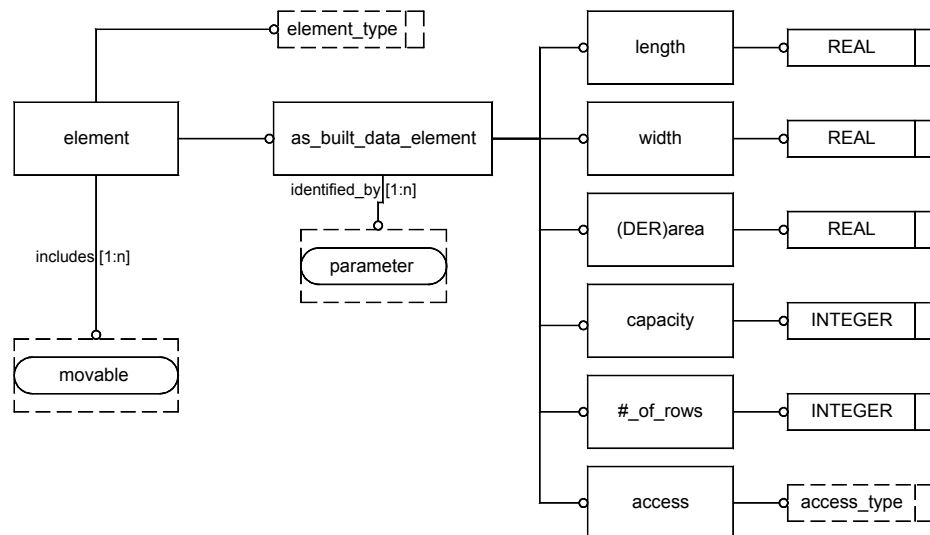


Figure 7.9: Courtroom elements schema.

7.3.3.3 Movables

Each element in a space zone includes one or more movables (*movable*). Movables are essentially *furniture* and *equipment* associated with a particular work area (figure 7.10). For instance, the reporter's station has only one piece of furniture (movable) where as a jury box can have as many as 21 or more piece of furniture (movable). The furniture may or may not be physically movable and the term 'movable' should not be taken literally. Relationships between movables are the key areas of research and design interest in many studies, although such data were not collected in this study. For instance, the *distance* between each pair of movables in a courtroom well (witness to judge, for instance) is of key interest to court designers. Similarly, the level difference between (*level_diff*) each pair of movable in a courtroom influences the lines of sight as well as the symbolic rendition of the courtroom setting. Angular dimension between movables is yet another example of movable relations. Furniture and equipment also have numerous attributes of interest. Such attributes include physical data on dimensions/capacity including *length*, *depth*, work surface height (*work_height*), floor level above the well (*floor_lvl*), edge-lip height of furniture (*lip_height*), and the percentage of sightlines obstructed from the user location (*sightline*). Environmental data in the lighting domain include the task illuminance (*task_illum*), vertical illuminance at the user location (*ver_illum*), task brightness (*task_brt*), surrounding brightness (*surround_brt*), background brightness (*bkgground_brt*), largest and brightest (potential glare) source from user location (*max_lum*), screen luminance for computer monitors (*screen_illum*), and screen

brightness from the user location (*screen_brt*). Elements and attributes associated with courtroom movables are outlined in table 7.8.

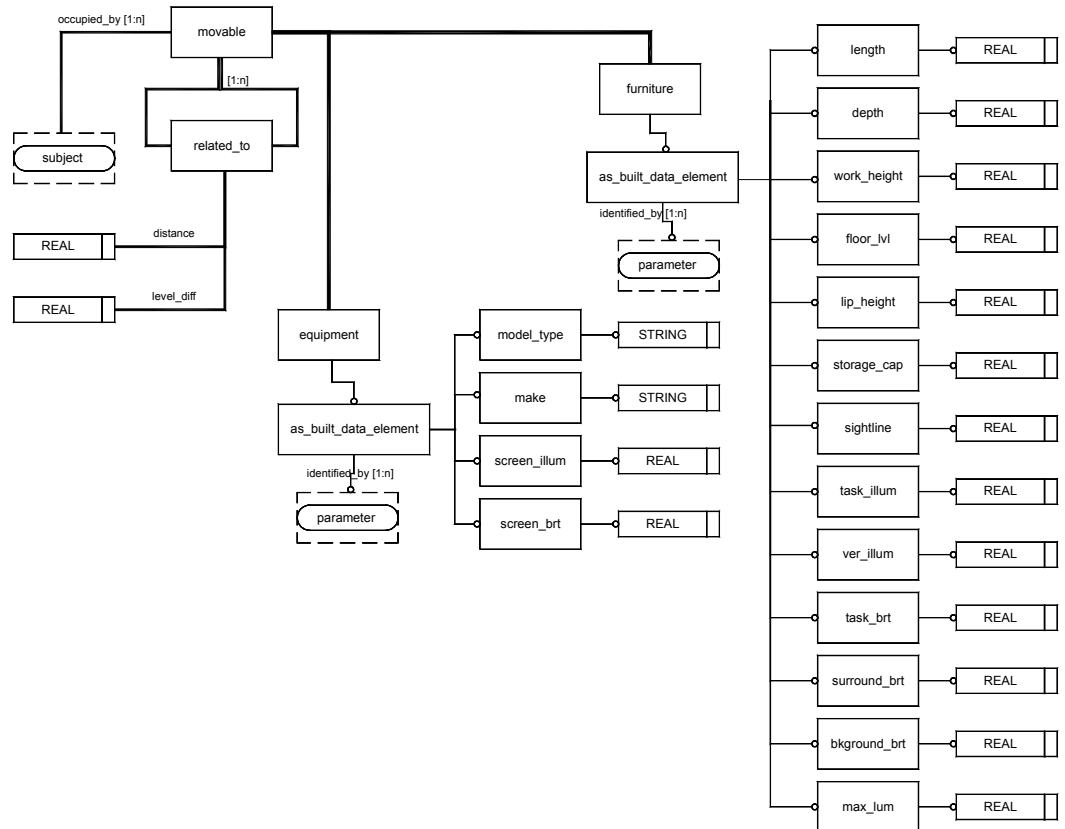


Figure 7.10: The movable schema.

Table 7.8: Elements and attributes associated with courtroom movables.

| Entity | Description |
|-------------------|--|
| <i>movable</i> | Furniture or equipment within elements in a space zone. |
| <i>furniture</i> | A type of movable; as in desk, cabinet, etc. |
| <i>equipment</i> | A type of movable; as in computer, monitor, etc. |
| <i>related_to</i> | An abstract entity that captures relationships between movables in a space. |
| <i>distance</i> | A type of relationship between movables; as in distance between judge and witness. |
| <i>level_diff</i> | A type of relationship between movables; as in level difference between judge and witness. |

Table 7.8 (continued)

| Entity | Description |
|-------------------------|--|
| <i>length</i> | A type of as-built physical data; as in length of a bench. |
| <i>depth</i> | A type of as-built physical data; as in depth of a reporter's station. |
| <i>work_height</i> | Short for work surface height. A type of as-built physical data; as in the work surface height of the deputy's station above floor level. |
| <i>floor_lvl</i> | Short for floor level. A type of as-built physical data; as in the floor level of the jury box in relation to the well. |
| <i>lip_height</i> | Short for edge-lip height. A type of as-built physical data; as in the height of lip around the bench measured from the well level. |
| <i>storage_capacity</i> | A type of as-built physical data; as in the storage capacity provided in the reporter's station. |
| <i>sightline</i> | A type of as-built physical data; as in the percentage of total sightlines blocked from the judge's position. |
| <i>task_illum</i> | Short for task illuminance. A type of environmental data in the lighting domain; as in the task illuminance value measured on the bench surface. |
| <i>ver_illum</i> | Short for vertical illuminance. A type of environmental data in the lighting domain; as in the vertical illuminance value measured at the user location in the witness box. |
| <i>task_brt</i> | Short for task brightness. A type of environmental data in the lighting domain; as in the task luminance value measured from the judge's location. |
| <i>surround_brt</i> | Short for surrounding brightness. A type of environmental data in the lighting domain; as in the surrounding luminance value measured from the judge's location. |
| <i>bkgground_brt</i> | Short for background brightness. A type of environmental data in the lighting domain; as in the background luminance value measured from the judge's location. |
| <i>max_lum</i> | Short for maximum luminance. A type of environmental data in the lighting domain; as in the luminance value of the largest, brightest source measured from the judge's location. |
| <i>screen_illum</i> | Short for screen illuminance. A type of environmental data in the lighting domain; as in the screen illuminance value measured on the bench monitor. |
| <i>screen_brt</i> | Short for screen brightness. A type of environmental data in the lighting domain; as in computer screen luminance value measured from the judge's location. |

7.3.4 User and POE data

A final area of the model holds evaluation data. EB studies typically focus on a particular setting type, a particular user type or a particular issue type. Data on settings are captured

in other parts of the model described above. Data on issues and users constitute the main focus of this schema. Typical POEs collect information on the characteristics of users in a space as well as on users' evaluation of the settings. It has been shown in EB research that user characteristics influence evaluation, and hence included in the model. Among other evaluation data, the date of evaluation is included to enable trend analyses, as well as before-after studies for quasi-experimental research designs. Finally, The evaluation of settings could be conducted on several issues or topics. The model includes data on issues specific to courtrooms. A classification structure for the issues, based on existing EB knowledge, is provided to ensure better comprehensiveness of the data structure.

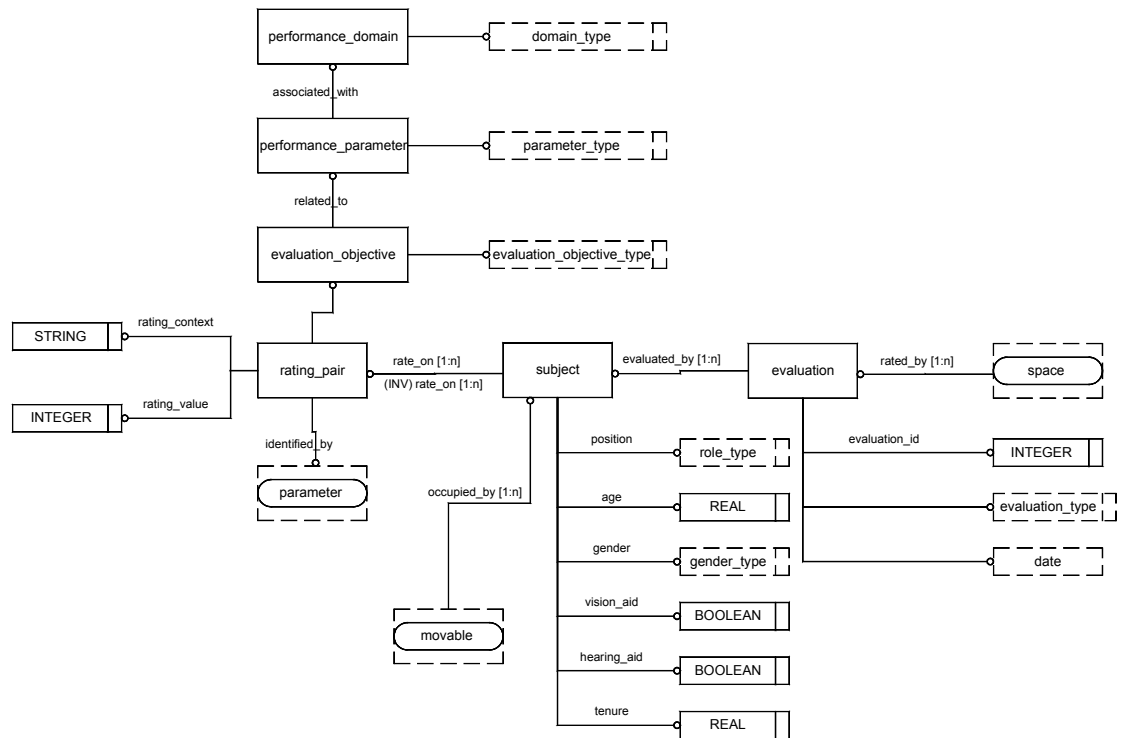


Figure 7.11: Schema representing data related to user and POE.

One or more users (*subject*; the term subject is used instead of users to provide a more generic term) occupy each movable (figure 7.11). The type of POEs considered in this study is the one where users of buildings-in-use are provided a questionnaire (paper or electronic) where they evaluate and rate their setting on an ordinal scale. As a result, each instance of evaluation data is associated with a specific user who, in turn, is associated with a particular movable in an as-built setting. On the other hand, POEs target one or more spaces in a facility. Each space is, thus, shown in the model to be rated by one or more evaluation studies (*evaluation*). Each evaluation has an associated *date*, and an *evaluation_type*. The attribute *evaluation_type* is included to explore the generality of the model to other evaluation types. In this study only POEs of one type has been considered. Typical POE studies collect various kinds of demographic data from the participants/subjects. In this study six types of data were collected. User *role_type* pertains to their position in the organization, for instance judge, reporter, and deputy/clerk. The *age* data collected is ratio scale, and provides the age of the user on the date of evaluation. User *gender_type* is a dichotomous variable with categories male and female. User *tenure* relates to the number of years the user has worked in the current position. Data on *vision_aid* and *hearing_aid* are yes/no Boolean type data that provide information on whether the user relies on the aid of hearing or visual devices for performing standard tasks in the courtroom. Each user or subject provides a rating on an ordinal scale related to one aspect of the setting. Those data are captured in the element *rating_pair* where *rating_context* describes the context of evaluation (or the specific thing being evaluated) and *rating_value* is the actual number on the ordinal scale assigned by the user.

The host of rating pairs provided by a user also needs some meaningful classification to support a search and query function. The entities *evaluation_objective*, *performance_parameter*, and *performance_domain*, provide the framework for meaningful classification. The latter two entities, *performance_parameter*, and *performance_domain* are parallel to the classification of as-built data types, discussed above. The use of the term ‘performance’ in the entities is intended to highlight that each evaluation study is designed to assess the performance of a building-in-use. Studies, however, differ in the kind of outcomes that are targeted. Many POE studies are designed to assess users’ satisfaction with their environment. Studies involving users’ preference related to aspects of a setting, users’ feelings, or users’ productivity in a setting are also common in traditional E-B research. Gifford (1997), for instance, lists performance, feelings, and stress as some key objective (outcome) areas in studies on office settings. Many POEs include user preference and productivity as study objectives. Further, some studies may include inquiries on two or more of these objective areas. The objective associated with a rating pair determines the evaluation objective of that particular rating pair. Further sub-classification of evaluation data into parameters and domains (as well as the classification of as-built data types into similar categories) also finds support in literature. For instance, Gifford (1997) contends, “the work environment can be considered not only as a collection of physical stimuli (noise, light, temperature, etc.), but also as a physical structure (size, furniture, hallways, etc) and as a symbolic artifact” (p.340). The segregation of data into environmental (‘physical stimuli’) and physical (‘physical structure’) provides a meaningful classification structure that corresponds well

with established arguments in literature. Instances of evaluation objective, performance parameter, and performance domain used for classification of POE data are included in table 7.9. Table 7.10 outlines the elements and attributes related to the evaluation schema.

Table 7.9: Evaluation objectives, parameters and data domains used to classify evaluation data.

| Evaluation Objective | Performance Parameter | Performance Domain |
|----------------------|--------------------------|--------------------|
| Task Performance | Physical | Configuration |
| User Preference | Environmental | Visual |
| User Satisfaction | <i>Social/ Financial</i> | Aural |

Table 7.10: Elements and attributes in the evaluation schema.

| Entity | Description |
|------------------------------|---|
| <i>evaluation</i> | An abstract entity that relates to all studies that assess buildings-in-use; as in POE study. |
| <i>evaluation type</i> | Provides identification to evaluation studies. |
| <i>date</i> | The date on which an evaluation is conducted. |
| <i>subject</i> | A generic term used for the users who participate in a POE study. |
| <i>role type</i> | User's position in the organization; as in judge, reporter, attorney. |
| <i>age group</i> | User's age on the date of evaluation. |
| <i>gender type</i> | User's gender. |
| <i>tenure</i> | User's length of work in the current position. |
| <i>vision_aid</i> | A Boolean data type asking subjects if they use vision aid to perform their tasks. |
| <i>hearing_aid</i> | A Boolean data type asking subjects if they use hearing aid to perform their tasks. |
| <i>rating_pair</i> | A pair of data types that describe the particular aspect of the environment being evaluated and the actual rating provided by the user. |
| <i>rating_context</i> | Describes the particular aspect of the environment being evaluated. |
| <i>rating_value</i> | Provides the actual rating provided by a user. |
| <i>evaluation_objective</i> | The general concept related to the measurement being conducted; as in task performance, satisfaction. |
| <i>performance_parameter</i> | The parameter within which an evaluation data resides; as in physical, environmental, social. |
| <i>performance_domain</i> | Domains of performance within each parameter; as in visual, aural, configuration. |

7.4 Database

Data can be stored in EXPRESS models. However storing data in a database management system has several potential advantages over storing data in the model (You, Yang et al., 2004). As opposed to storage of data in a file system, the above authors list the following as advantages with using relational databases: wide variety of implementations, common availability in the AEC industry, and extensive interfaces, among others. Further, the authors outline a formal way to map EXPRESS schemas to relational database tables, although standard implementation methods for translating STEP schemas to relational databases do not exist. Some of the key issues addressed in the above paper match the way the current EXPRESS-G model was mapped/translated into a relational database. The key steps are described below.

The database reflecting the model described in section 7.3 was created using MS ACCESS software. In essence, each subtype entity, and corresponding attributes in the model, were translated into a table in MS ACCESS. A single subtype table was created for each subtype, and subtype attributes specific to the entity was included in the table. Further, the tables were created only for end-node entities, and instances from the POEs were used to populate the tables related to the end-node entities. The use of identical primary keys helped combine partial tables, and reflected single entities in the EXPRESS model.

Most attributes in the end-node tables involve basic data types (mostly) common to EXPRESS as well as relational databases. Integers, real numbers, strings, and Booleans, were the most common basic data type used in the model as well as the database. Enumeration type, available in EXPRESS, was also available in ACCESS, and translated accordingly. Possible complications involving translation of aggregation types and select types, in EXPRESS, did not arise, since such data types were not used in the model.

The translation of entities into separate tables enabled an important functionality. By creating unique identifiers (Ids) for sites, buildings, evaluations, users, and other key entities, buildings as well as evaluation studies (POEs) can be identified, and distinguished from other POEs or buildings. Further, each evaluation study is dated, thus enabling the possibility of trend analysis in the long run.

Relations between entities in the model were translated into table relationships using the built in functions available in ACCESS. The use of one-to-one and one-to-many relationships, and the various combinations of join characteristics enabled a reasonable translation of the model into tabular structures in ACCESS. Queries were also developed using the built-in query function available in ACCESS. While the number and types of queries that could be developed could be many, the primary focus of the querying was to generate information from the data that could provide support to design decision-making and academic inquiry. The subsequent chapters describe several scenarios of use through query functions, supported by the model developed in this study. Such scenarios relate to

both design/design review phases of a building's procurement as well as to academic inquiries.

7.5 Summary

The data fields identified in chapter 6 were interrogated to identify structures that could provide meaningful placements for the fields. A conceptual model was developed using EXPRESS-G data modeling language. The EXPRESS-G schemas can be considered as four main chunks of data structure: identifiers, enclosure system, functional clusters, and evaluation data. A database reflecting the model was developed using MS ACCESS. The database was populated with data collected during POEs of 26 state and federal courtrooms.

Chapter 8

Query Generated Outcomes

The type of data structuring developed in this study enables querying and extraction of several types of information from the database. A class of information that could be retrieved pertains to information support during design and design review. Support for design and design review also constitutes a portion of the next chapter. The fundamental distinction between the scenarios discussed in this chapter and the next is that the end-users, in the scenarios outlined here, directly interact with the POE data. Scenarios in the next chapter deal with outputs related to research findings from the POE data. Six possible scenarios of information support are dealt with in this chapter:

- 8.1 Explore cases
- 8.2 Analyze precedence
- 8.3 Identify best and worst cases
- 8.4 Rate design decisions,
- 8.5 Extract raw data
- 8.6 Predict performance
- 8.7 Summary

The support scenarios discussed in this chapter are not real-time interactive (high frequency) support that many computing tools offer, where the system provides one-on-one feedback as the design proceeds. Rather, it is envisaged that the information support

(more specifically for the testing scenarios) would be sought at the end of a design cycle (see chapter 2), along the multi-cyclic path of design progression. The end-user could be a designer or an analyst in a design office, who would use the information to assess the predicted performance of a cluster of design decisions.

8.1 Explore cases

At the most basic level the data constitutes as a case library. It should be noted that the portion of the data structure discussed in the previous chapter that deals with schemas on building objects is a simplified version of the more extensive and comprehensive model developed under the ISO-STEP program. Building object schemas in the model developed here serve as placeholders for the more detailed schema developed in STEP, and it is assumed that the later would be used in any practical application (the current model holds limited data on building objects, and may not represent the true potential of the integrated model). The presence of comprehensive as-designed data in a single data structure enables the data structure to be used as a case library of buildings and building types. In contrast with as-designed data (data pertaining to designer's intentions/predictions reflected in the design), the source of as-built data (or data from buildings-in-use) are principally available from POE studies. Thus the extent of data collected during typical POE studies would dictate the nature and extent of information on buildings-in-use that could be retrieved from the data structure. The combination of as-designed and as-built data on any particular building (which may also include graphic and other data types) would serve as a rich repository of building information that could be queried

based on the need of any particular design situation. While data on a particular building could be extracted by building name, the buildings in the database could be searched based on key attributes to enable more focused query of the data, based on criteria or constraints related to any specific project. Such attributes, currently, include the jurisdiction, judicial district, city, attributes of courtroom, and attributes of courtroom element. Data could also be extracted by date of evaluation. More number of attributes for focused search could also be added to the schema on site, project, building, and use space, to create enhanced capability for data query and retrieval. Such attributes could include environmental parameters such as climatic zone, physical parameters such as site characteristics, type of evaluation, evaluation team, or more abstract socio-political constructs like openness. The end-user may go to a known target courthouse directly, or query the database to come up with potential candidates for exploration.

An example of case exploration could be the Superior Courts courtrooms in the Newton County Courthouse. The end-user is assumed to have heard about the courtroom and would like to get detailed information on it. By selecting the courthouse name directly from the attribute list of building, the end user could get access to data on two courtrooms in the courthouse that exist in the database. Such data includes environmental as well as physical parameters. Table 8.1 shows the result of a query that includes the (available) data on physical characteristics of courtroom number 2 and 3 in Newton County Courthouse. Table 8.2 shows the result of a similar query on acoustical characteristics of the courtroom. The query could also go deeper to extract data on courtroom elements, for

instance the physical characteristics of the bench in the courtrooms as shown in Table 8.3.

Table 8.1: Query output showing courtroom level physical data in Newton County Courthouse.

| building_name | use_type | use_space_type | use_space_number | length | width | area | height | volume | capacity |
|--------------------------|-----------------|----------------|------------------|--------|-------|---------|--------|----------|----------|
| Newton County Courthouse | superior courts | courtroom | Courtroom-2 | 38.83 | 28.92 | 1086.05 | 14.16 | 15378.47 | 69 |
| Newton County Courthouse | public | waiting | Courtroom-2 | | | 0 | | | 9 |
| Newton County Courthouse | superior courts | courtroom | Courtroom-3 | 38.75 | 33.33 | 1160.69 | 14.08 | 16342.52 | 67 |
| Newton County Courthouse | public | waiting | Courtroom-3 | | | 0 | | | 9 |

Table 8.2: Query output showing courtroom level acoustical data in Newton County Courthouse.

| building_name | use_type | use_space_type | use_space_number | r_time | backgr_noise | noise_movement |
|--------------------------|-----------------|----------------|------------------|--------|--------------|----------------|
| Newton County Courthouse | superior courts | courtroom | Courtroom-2 | 0.74 | 21 | 62.77 |
| Newton County Courthouse | superior courts | courtroom | Courtroom-3 | 0.74 | 20 | 60.33 |

Table 8.3: Query output showing Bench physical data in Newton County Courthouse.

| building_name | use_type | use_space_type | use_space_number | element_type | length | depth_or_width | height_of_worksurface | edge_lip_height | floor_level |
|--------------------------|-----------------|----------------|------------------|--------------|--------|----------------|-----------------------|-----------------|-------------|
| Newton County Courthouse | superior courts | courtroom | Courtroom-2 | bench | 5 | 1.92 | 2.5 | 4.58 | 1.5 |
| Newton County Courthouse | superior courts | courtroom | Courtroom-3 | bench | 5 | 1.92 | 2.42 | 4.58 | 1.5 |

Alternately, the end-user could search the database based on certain criteria and select a courthouse from the result list. For instance, the user could be interested in state courthouses as opposed to federal ones. Since the database currently holds data only from Georgia courts, one step in the search sequence (of selecting the state) is not discussed here. Among the Georgia state courthouses, the user could be interested in looking at courtrooms in the 10th judicial district. By choosing appropriate attributes on building, the search could be narrowed to available data on four courthouses in the district on which data exists (table 8.4). The user could select one or more of the courthouses and select particular courtrooms within those courthouses to explore. The final outputs would be identical to the ones shown in tables 8.1, 8.2, and 8.3, and hence not elaborated further.

Table 8.4: Query output showing all courthouses in 10th judicial district of Georgia on which data is available.

| city_name | state_name | jurisdiction | district | building_name |
|--------------|------------|--------------|--------------|-----------------------------------|
| Monroe | Georgia | State | 10th Georgia | Walton County Courthouse-Civil |
| Monroe | Georgia | State | 10th Georgia | Walton County Courthouse-Criminal |
| Watkinsville | Georgia | State | 10th Georgia | Oconee County Courthouse |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse |
| Covington | Georgia | State | 10th Georgia | Newton County Courthouse |

A value addition to the queried data occurs owing to the integration of user evaluation data with the as-built data. For instance, knowledge on the well area in courtroom number 3 in Clarke County Courthouse could be valuable to the end-user interested in the 10th judicial district of Georgia. Size of the courtroom well was identified as an important variable through the exploratory studies at the beginning of this thesis. Further, well size in courtrooms constitutes a (statistically) significant parameter of importance (as is discussed in chapter 9) that influences the efficiency of courtroom proceedings. What adds value to this knowledge is the fact that the end-user could also get an idea about how users of the courtroom have rated the well size for the type of task they perform in that particular courtroom (for ascertaining the privacy of the users surveyed in this study, the role/position of the user is intentionally not revealed; this is done to confirm with the guidelines provided by the Georgia Institute of Technology, IRB). Table 8.5 shows the result of the query that was created to extract the well size in courtroom-3 in Clarke County Courthouse. It also shows how the users of the courtroom evaluated the well size on a seven point ordinal scale that ranges between 1 and 7. Through systematic querying, an end-user could gain access to a wide range of as-built data on a particular case, as well as on how users of the space have evaluated the design parameter under question. While

case libraries help end-users explore individual cases, another form of output of the data model involves more generalized data extraction across cases, which is discussed next.

8.2 Analyze precedence

Yet another output of a comprehensive building object schema is precedence analysis. Precedence analysis is typically conducted during pre-programming and programming phases of a project. The objective is to gain some understanding on the range of values of a certain design parameter that has been implemented in existing buildings. Programmers typically survey existing facilities to get the data. In many cases, especially in large organizations with well-documented portfolios such information could possibly be gathered from the departmental files or archives. The output of the data model described here contributes in two significant ways. The information could be made available through web browsers, thus expanding the number and types of end-users who could get access to the data. Further, the end-user could follow the steps explained in section 8.1, after a precedence analysis, to get a more in-depth knowledge on how the users have rated the supportiveness of the environment for the tasks they perform.

Table 8.5: Query output showing the well dimensions in Clarke County Courthouse, as well as the way courtroom users, surveyed in the POE, have rated the well for the tasks they perform in the courtrooms.

| city_name | state_name | jurisdiction | district | building_name | use_space_number | space_zone_type | length | width | user_id | rating_context_type | rating |
|-----------|------------|--------------|--------------|--------------------------|------------------|-----------------|--------|-------|---------|---------------------|--------|
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur139 | well size | 6 |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur140 | well size | 3 |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur140.1 | well size | 6 |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur141 | well size | |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur143 | well size | 5 |
| Athens | Georgia | State | 10th Georgia | Clarke County Courthouse | Courtroom-3 | courtroom_well | 25.33 | 38.75 | ur143.1 | well size | 6 |

Despite conventional wisdom associating precedence analysis to the programming phases, it also offers information support during early design phases. That form of support is akin to the ‘imaging support’ phase articulated by Zeisel (1984). For instance, a designer who might be highly experienced in the design of other building types may not possess any/sufficient knowledge on courtrooms as setting types. Several courts systems have created guidance documents (including the federal courts), but such documents serve more as a starting anchor to the design process rather than as a design support information system. It is, thus, conceivable that a designer at the initial phases of a

project might want to explore the general range of values of design parameters that exist in buildings-in-use. In fact, it is customary for design team members of new courthouse projects to visit several courthouses before starting their design task. The site visits, in a way, assist in defining a boundary around a solution space (or defining a fuzzy solution space) within which the initial design work would proceed. The database enables a survey of key courtroom parameters to provide an initial (from a design viewpoint – fuzzy) impression about the range of values of one or more attributes of a building object that exist (depending on the number of cases living in the database).

Arguably, it is not necessary for the design team to restrict themselves to the boundary they create during their initial exploration. It is possible that the design team arrives at decisions that are very different from what exists in current buildings-in-use. However, the precedence analysis would, possibly, trigger additional thoughts in the designer's creative endeavors as one goes through the initial fuzzy imaging process, as well as during creative leaps. In other words, a designer would adopt certain design decisions with the full knowledge that such decisions constitute outliers, which may trigger more intense mapping between design schemas, analogies and metaphors during design.

Analyzing precedence may not prove to be the sole domain of facility programmers and designers. It may prove constructive during design review phases. For instance, in a situation where several alternative designs are provided by one design firm, or several design firms are invited to submit their best design proposal, access to a database that enables precedence analysis could prove to be informative. It could enable the review team to isolate the non-traditional designs from the traditional ones, and interrogate

further to extract the fundamental essence behind each type of design alternative. That could create a dialogue process, which will offer a more meaningful (and enhanced) communication media between decision makers from varied fields of origin (including designers).

The database, currently, holds as-built data on a wide range of attributes at the courtroom level, courtroom zone level as well as element level. A good example of precedence analysis could be the seating capacity of the spectator gallery. How many spectators should it hold? That depends on the type of courtroom under question. Assuming that a hypothetical programmer or designer or member of a review team is focusing on Superior Courts courtrooms. As elaborated in chapter 4, the spectator gallery serves numerous functions, some related to efficiency and others to symbolic requirements. The gallery capacity influences how well, for instance, a jury selection process is conducted, with sufficient space for the juror pool as well as family members of the defendant, public, and representatives of the media. During typical case proceedings, however, the galleries remain generally under-occupied (except in high-profile cases). In such situations they influence the auditory environment, since gallery size also influence decisions regarding courtroom volume. An end-user could query the database to obtain a fuzzy vision on the range of seating capacities in courtroom spectator galleries that exist in buildings-in-use in Georgia state Superior Courts courtrooms (figure 8.1, table 8.6). The output (shown here in separate applications, but could be generated automatically through well programmed web applications) provides some initial statistics about the range, mean value, median, and the modal category for gallery capacities in Superior Courts

courtrooms in Georgia. As mentioned earlier, the end-user also has the choice to use some of the steps outlined in other sections in this chapter to narrow the search after this initial step, as well as integrate user evaluation data with particular attribute values they are interested in.

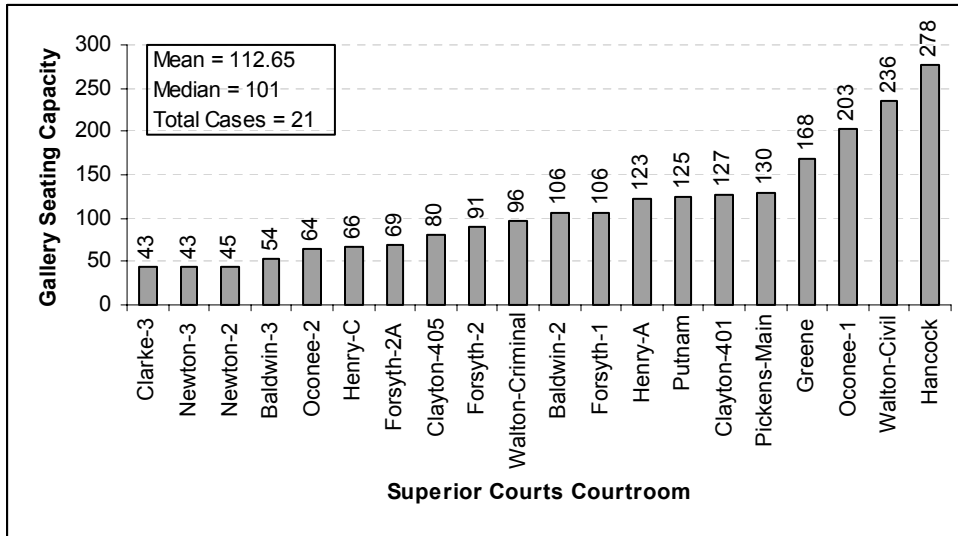


Figure 8.1: Precedence analysis showing the range of gallery capacities in Georgia's Superior Courts courtrooms.

Table 8.6: Query output showing gallery seating capacities in Georgia Superior Courts courtroom from which figure 8.1 was generated.

| jurisdiction | use_space_type | use_type | space_zone_type | capacity | building_name | use_space_number |
|--------------|----------------|-----------------|-------------------|----------|---------------------------|------------------|
| State | courtroom | superior courts | courtroom_gallery | 106 | Baldwin County Courthouse | 2 |
| State | courtroom | superior courts | courtroom_gallery | 54 | Baldwin County Courthouse | 3 |
| State | courtroom | superior courts | courtroom_gallery | 106 | Forsyth County Courthouse | Courtroom-1 |
| State | courtroom | superior courts | courtroom_gallery | 91 | Forsyth County Courthouse | Courtroom-2 |
| State | courtroom | superior courts | courtroom_gallery | 69 | Forsyth County Courthouse | Courtroom-2A |
| State | courtroom | superior courts | courtroom_gallery | 130 | Pickens County Courthouse | Main Courtroom |

Table 8.6 (continued)

| jurisdiction | use_space_type | use_type | space_zone_type | capacity | building_name | use_space_number |
|---------------------|-----------------------|-----------------|------------------------|-----------------|-----------------------------------|-------------------------|
| State | courtroom | superior courts | courtroom_gallery | 127 | Clayton County Courthouse | Courtroom-401 |
| State | courtroom | superior courts | courtroom_gallery | 80 | Clayton County Courthouse | Courtroom-405 |
| State | courtroom | superior courts | courtroom_gallery | 123 | Henry County Courthouse | Courtroom-A |
| State | courtroom | superior courts | courtroom_gallery | 66 | Henry County Courthouse | Courtroom-C |
| State | courtroom | superior courts | courtroom_gallery | 236 | Walton County Courthouse-Civil | Civil Courtroom |
| State | courtroom | superior courts | courtroom_gallery | 96 | Walton County Courthouse-Criminal | Criminal Courtroom |
| State | courtroom | superior courts | courtroom_gallery | 203 | Oconee County Courthouse | Courtroom-1 |
| State | courtroom | superior courts | courtroom_gallery | 64 | Oconee County Courthouse | Courtroom-2 |
| State | courtroom | superior courts | courtroom_gallery | 125 | Putnam County Courthouse | |
| State | courtroom | superior courts | courtroom_gallery | 168 | Greene County Courthouse | |
| State | courtroom | superior courts | courtroom_gallery | 278 | Hancock County Courthouse | |
| State | courtroom | superior courts | courtroom_gallery | 43 | Clarke County Courthouse | Courtroom-3 |
| State | courtroom | superior courts | courtroom_gallery | 45 | Newton County Courthouse | Courtroom-2 |
| State | courtroom | superior courts | courtroom_gallery | 43 | Newton County Courthouse | Courtroom-3 |

It must be acknowledged, however, that similar functionalities are currently available in other implemented systems, a noteworthy example being the CourtsWeb project, involving federal courthouses, developed at the Georgia Institute of Technology. The main difference is in the value addition achieved through integration of user evaluation data at as-built data (as shown in table 8.5). The integration of evaluation data with as-built data also results in the other scenarios of design support discussed in this chapter. A possible step an end-user could make after proceeding through the phases involving

fuzzy-vision and defining a solution space is to start assigning actual values to a particular design parameter of interest. At that stage it might be of interest to know the range of parameters that has been evaluated positively by the occupants, or otherwise, which is addressed next.

8.3 Identify best and worst cases

Without access to knowledge on buildings-in-use the only way for a designer to learn to avoid mistakes (or replicate good decisions) is through personal experience, and those obtained through communications with colleagues. Access to a database with evaluation data is presumed, here, to support design decision making that distances itself from instances with unfavorable ratings, and gravitates towards those that offer more favorable ones. Every designer makes mistakes and learns through those mistakes. What the data model enables is the dissemination of lessons learned to a wider audience. At a higher level of aggregation, one could begin to find patterns of practices that are evaluated unfavorably, or otherwise. The findings may also prompt end-users to think critically about the matter and hypothesize about possible causal association between environmental design decisions and favorable or unfavorable outcomes. The outcome may also be viewed as a way to further fine-tune the solution space arrived at through precedence analysis during pre-design or early design phases.

While the criteria on which cases could be evaluated could be many, this study uses user evaluation data from POEs as the instrument for assessment. User's evaluation of the

supportiveness of their work environment to the tasks they perform, on a seven point ordinal scale, is used here for assessing the products of design decisions in courtroom settings. Typically, the seven-point scale vacillates between very good rating (very supportive environment) at one end of the scale and very bad rating (very unsupportive environment) at the other. The exact criterion (tolerance level) that distinguishes very bad or very good ratings from the rest is left to the user. It is assumed that the level of importance of a certain design decision changes depending on the context, and it is best to leave the decision regarding tolerance level to the end-user as opposed to hard coding it in the model.

In the database, the user would be required to go through two parallel queries. One query would be on as-built data and the other on user evaluation of the aspect of the as-built environment that the end-user is querying. A criterion is then defined based on which the data would be further filtered. For instance, a criterion could be all user ratings less than 2 on the seven-point scale to isolate unfavorable instances (note that the user decides whether the tolerance point is 2, 3 or any other level). In the example shown below the end-user wishes to learn about the levels of illuminance that have been rated high by users, for tasks involving reading printed documents. It should be noted that the search could be more focused by using one or more of the attributes discussed previously. For instance, the end-user might wish to extract data on Superior Courts courtrooms, may look only at bench illuminance, or adopt one or more strategies for focused search. After selecting the work surface illuminance as the target variable, the end-user selects reading task from a list of evaluation data related to visual tasks. The end-user, subsequently,

provides 5 or more as the defining criteria for good illuminance for reading tasks. The outcome, shown in table 8.7 and figure 8.2, shows the proportion of users within each interval of illuminance level that have rated a particular illuminance level above 5. It looks plausible from the chart that the best possibilities of high user rating are associated with illuminance ranging between 30 and 65 FTC. Illuminance values below and above this range may not be rated as favorably. As suggested earlier, the end-user may decide not to be guided by the output. The output, however, triggers some crucial thoughts, such as should one spend more and provide high illuminance levels, and for what reason – writing task, courtroom symbolism?

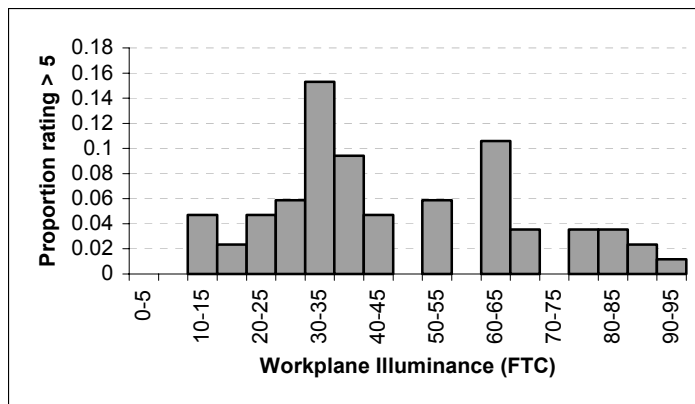


Figure 8.2: Chart generated from table 8.7 showing the percentage of users rating their environment greater than 5 for reading tasks, within each interval of illuminance level.

Table 8.7: Query output (partial) showing user rating of their environment for reading tasks and corresponding level of illuminance on their work surface.

| element_id | element_type | work_plane_illuminance | user_id | rating_context_type | rating |
|------------|------------------|------------------------|---------|---------------------|--------|
| e001 | bench | 30.6 | ur001 | reading task | 7 |
| e002 | deputy_station | 30.5 | ur002 | reading task | 7 |
| e003 | reporter_station | 31.8 | ur003 | reading task | 6 |
| e007 | bench | 30.1 | ur007 | reading task | 7 |
| e031 | bench | 35.1 | ur031 | reading task | 1 |
| e032 | deputy_station | 28.2 | ur032 | reading task | 4 |
| e033 | reporter_station | 34.9 | ur033 | reading task | 6 |
| e035 | attorney_desk | 38.7 | ur035 | reading task | 6 |
| e035 | attorney_desk | 38.7 | ur035.1 | reading task | 7 |
| e044 | deputy_station | 79.3 | ur044 | reading task | 1 |
| e044 | deputy_station | 79.3 | ur044.1 | reading task | 4 |
| e047 | attorney_desk | 62.8 | ur047 | reading task | 7 |
| e101 | attorney_desk | 14.3 | ur101 | reading task | 6 |
| e103 | bench | 71.5 | ur103 | reading task | 5 |
| e104 | deputy_station | 41.2 | ur104 | reading task | 6 |
| e104 | deputy_station | 41.2 | ur104.1 | reading task | 3 |
| e107 | attorney_desk | 69.1 | ur107 | reading task | 5 |
| e109 | bench | 26.5 | ur109 | reading task | 3 |
| e110 | deputy_station | 23.3 | ur110 | reading task | 6 |
| e111 | reporter_station | 29.7 | ur111 | reading task | 3 |

A similar example of outcome is shown in figure 8.3 and table 8.8, but related to the physical variables in courtrooms. Courtroom height is conventionally regarded as contributing to its symbolic attributes. High ceiling, it is believed, portray the importance of law and the dignity of the judicial system. Courtroom height also influences other environmental and economic parameters, and hence could be the subject of investigation in design and design review. In this case, the end-user extracts data on courtroom height from the as-built data tables. Subsequently, the end-user extracts user ratings on the level of dignity rendered by their courtroom geometry from the evaluation data tables. The end-user in this case intends to look at courtroom heights that have been rated 5 or less as

unfavorable outcome, since symbolism constitutes a vital area of courtroom design. The outcome provides the proportion of users within each interval of courtroom height that have rated their courtroom 5 or less on the seven-point scale. A cursory review of figure 8.3 suggests that unfavorable ratings are generally associated with courtrooms that are less than 12 feet high. It may be plausible that beyond 12 feet other factors become important contributors to courtroom symbolism. Once again, whether heights less than 12 feet should be avoided is best left to the designer.

The outcomes could also be viewed as supplementing the knowledge built into design guides and standards. The standards for illumination in workplaces, for instance, states general levels of desirable illuminance based on task characteristics. It does not provide, for instance, information on the levels appropriate in courtrooms or, more specifically, for court reporters. From such a perspective the database adds information support to the ones provided by design guides and standards.

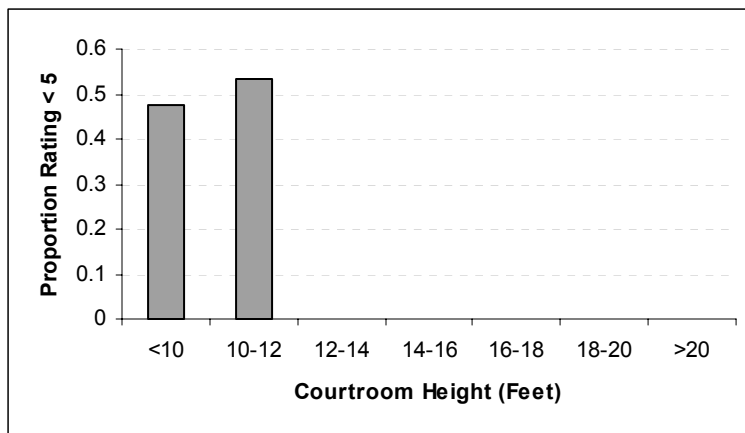


Figure 8.3: Chart generated from table 8.8 showing the number of users rating their courtroom geometry less appropriate for the dignity it should convey (<5), within each interval of courtroom heights.

Table 8.8: Query output showing user rating of symbolic attribute of their courtroom and corresponding courtroom heights.

| use_space_type | height | user_id | rating_context_type | rating |
|----------------|--------|---------|------------------------------|--------|
| courtroom | 10.5 | ur021 | courtroom geometry - dignity | 4 |
| courtroom | 10.5 | ur023 | courtroom geometry - dignity | 5 |
| courtroom | 10.5 | ur024 | courtroom geometry - dignity | 5 |
| courtroom | 9.58 | ur030 | courtroom geometry - dignity | 3 |
| courtroom | 10 | ur031 | courtroom geometry - dignity | 3 |
| courtroom | 10 | ur032 | courtroom geometry - dignity | 4 |
| courtroom | 10 | ur033 | courtroom geometry - dignity | 4 |
| courtroom | 10 | ur035.1 | courtroom geometry - dignity | 2 |
| courtroom | 9.63 | ur037 | courtroom geometry - dignity | 3 |
| courtroom | 9.63 | ur041 | courtroom geometry - dignity | 2 |
| courtroom | 9.63 | ur041.1 | courtroom geometry - dignity | 2 |
| courtroom | 9.63 | ur044 | courtroom geometry - dignity | 2 |
| courtroom | 9.63 | ur044.1 | courtroom geometry - dignity | 4 |
| courtroom | 9.63 | ur047 | courtroom geometry - dignity | 2 |
| courtroom | 9.83 | ur104 | courtroom geometry - dignity | 3 |
| courtroom | 9.83 | ur104.1 | courtroom geometry - dignity | 5 |
| courtroom | 9.83 | ur107 | courtroom geometry - dignity | 5 |
| courtroom | 10 | ur115 | courtroom geometry - dignity | 5 |

Yet another utility of the outcomes could be in the domain of providing decision support during the design review phases. It is conceivable that reviewers of alternative design schemes have a list of design parameters that they consider crucial, and hence would (at least partly) evaluate the alternative design schemes based on how many of the design decisions fall within the zone of good practices and how many in the other extreme. The procedure for querying the database, as well as the outcome, would be identical to the two examples shown here.

While this stage of information support, from a design and programming perspective, could be viewed as supporting decisions for arriving at a (or fine tuning) fuzzy solution space, a separate type of outcome could be used to evaluate decisions at a later phase in design, when a hypothetical end-user has initiated the design process and arrived at the first (or subsequent) solution.

8.4 Rate design decisions

This type of decision support relates to the ‘testing’ phase propounded by Zeisel (1984). The assumption here is that the end-user has initiated the design work and (with or without the aid of the three scenarios discussed above) arrived at a certain solution. The solution needs to be tested to see if it confirms with criteria laid down in the program, or expressed by the stakeholders/ clients/ owners. Such criteria could also originate from the designer. On the surface, this scenario, and associated steps and outcomes may look similar to the ones explained in section 8.3. However, there is a fundamental difference. The main difference relates to the phase of design where the support is provided, and the type of use made out of the information. Identifying best and worst cases is envisaged to occur at the pre-design phases, when the end-user is attempting to create a solution space to work within. In contrast, the rating scenario discussed here is envisaged to occur once a design solution has been arrived. Since design is believed to proceed in a cyclic manner, this scenario of decision support could occur at any of the sub-phases of design development when the end-user could use some testing support.

In essence, the end-user, after arriving at a solution, could use the database to learn how well a certain design decision has been rated by users in similar settings. This is different from finding out which range of values related to a certain design decision have been rated very low or very high by courtroom users. It is conventionally accepted that the design process involves a series of compromises between conflicting but important areas of design decisions. While, ideally, a design process could aim to create an environment that is rated high on each of the areas of importance, conflicts are inevitable. It is conceivable, thus, that the end-user, while going through each cycle of imaging, performs a series of compromises to arrive at a solution. At those stages of design development the end-user could get information on user ratings for one or more areas of importance. That could provide the starting points for the subsequent phase of design imaging, and more compromises. The focus is less on whether the end-user would use the information for improvement, and more on the possibility that the compromises arrived at during imaging processes occur within a more informed domain of decision-making.

The query process is similar to the one explained in section 8.3 with some differences. The end-user runs two parallel queries. One query focuses on as-built data, and the other on user ratings related to the as-built data being queried. The end-user subsequently could provide a range value, or a point value, of a certain design parameter on which mean user ratings are being sought. The outcome provides the mean rating for each value or interval of the design parameter on which the query was fired. For instance, figure 8.4 and table 8.9 show the result of a query where the hypothetical end-user has arrived at a gallery seating capacity of 55 seats. As discussed in earlier chapters, the gallery capacity is an

important variable that is understood to influence the efficiency of courtroom function during pre-trial and jury selection phases. The end-user is more interested in Superior Courts courtrooms. By querying the database the user extracts data on gallery seating capacity in all Superior Courts courtrooms in Georgia that live in the database. A parallel query extracts user ratings on gallery capacities from users of Superior Courts courtrooms. The outcome displays the mean rating level for each interval of gallery capacity. It shows that by deciding on 55 seats the end-user may end up in a lesser-rated courtroom. The outcome also shows that a seating capacity of at least 60 would provide an above average support to the tasks conducted in a Superior Courts courtroom. Further, courtrooms with more than 100 seats in the gallery may not prove to be as supportive. The end-user, at this point, may (or may not) reevaluate the decision to provide 55 seats in the gallery.

As discussed in previous chapters, sizes of courtroom zones (including the gallery) also influence the acoustical characteristics of the courtroom environment. Increasing gallery seats may result in unfavorable acoustic conditions for speech clarity in the well area. Figure 8.5 and table 8.10 shows the outcome of a possible parallel exercise performed by the end-user after having modified the gallery seating capacity. The end-user wishes to test the (hypothetical) reverberation time of 0.9 sec, which resulted from the previous modification, against user evaluation of speech conditions based on reverberation time data. The user proceeds through an identical process of parallel query. Only this time the as-built data constitutes the reverberation time and the user ratings pertain to speech clarity in the well. By providing a range of 0.6 to 1.1 second as the range within which to

survey the database, the end-user notes that a target reverberation time of 0.9 seconds have been associated with good ratings for speech clarity. Of course, the rating could be improved by bringing the reverberation time within 0.7 and 0.8 seconds, but such a step need not be attempted. The one aspect to watch for is reverberation time beyond 1.0 second. This may trigger a scan for best and worst cases as described in section 8.3.

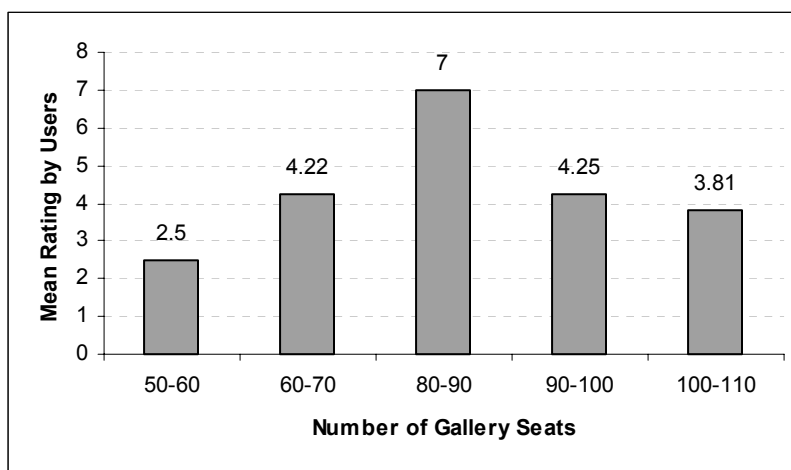


Figure 8.4: Chart generated from table 8.9 showing mean user rating for each interval of gallery seating capacity.

Table 8.9: Query output showing (partial) user rating of gallery capacity in their courtroom and corresponding actual seating capacity in Superior Courts in Georgia.

| space_zone_type | capacity | user_id | rating_context_type | rating | jurisdiction |
|-------------------|----------|---------|---------------------|--------|--------------|
| courtroom_gallery | 43 | ur153 | gallery capacity | 5 | State |
| courtroom_gallery | 43 | ur155 | gallery capacity | 3 | State |
| courtroom_gallery | 43 | ur156 | gallery capacity | 5 | State |
| courtroom_gallery | 45 | ur145 | gallery capacity | 1 | State |
| courtroom_gallery | 45 | ur146 | gallery capacity | 4 | State |
| courtroom_gallery | 45 | ur146.1 | gallery capacity | 3 | State |
| courtroom_gallery | 45 | ur147 | gallery capacity | 4 | State |
| courtroom_gallery | 45 | ur149 | gallery capacity | 3 | State |
| courtroom_gallery | 45 | ur150 | gallery capacity | 5 | State |

Table 8.9 (continued)

| space_zone_type | capacity | user_id | rating_context_type | rating | jurisdiction |
|------------------------|-----------------|----------------|----------------------------|---------------|---------------------|
| courtroom_gallery | 54 | ur025 | gallery capacity | 3 | State |
| courtroom_gallery | 54 | ur030 | gallery capacity | 2 | State |
| courtroom_gallery | 64 | ur115 | gallery capacity | 5 | State |
| courtroom_gallery | 64 | ur116 | gallery capacity | 6 | State |
| courtroom_gallery | 64 | ur117 | gallery capacity | 6 | State |
| courtroom_gallery | 64 | ur119 | gallery capacity | 5 | State |
| courtroom_gallery | 66 | ur091 | gallery capacity | 6 | State |
| courtroom_gallery | 66 | ur095 | gallery capacity | 3 | State |
| courtroom_gallery | 69 | ur044 | gallery capacity | 1 | State |

The support system could also be viewed from a design review perspective. Taking the gallery seating capacity as an example, several design alternatives could come up with varying seating capacities. This is truer for federal courts where the U.S. Courts Design Guide has laid out prescriptive standards for courtroom sizes. As a result the designer, conceivably, proceeds through a compromise between the well area and area in spectator gallery. By running queries as described above, the design review team could come up with some idea about the possible user ratings for each of the alternatives under consideration. Further, as explained earlier, the query could be focused on a particular courtroom type, a particular judicial district, or any other attribute of buildings, courtrooms and elements that the end-user could think of for adding precision to the information extracted.

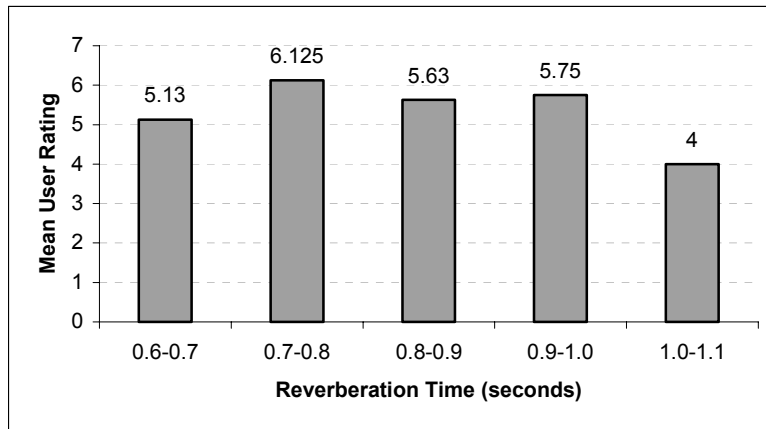


Figure 8.5: Chart generated from table 8.10 showing mean user rating for speech clarity within each interval of reverberation time.

So far the assumption has been that the end-user is comfortable with the software and system that hosts the database. It may be possible that the end-user is more conversant with a different software or system. In such a scenario the ability to extract raw data could expand the potential of the support mechanism elaborated here.

Table 8.10: Query output showing (partial) user rating of speech clarity in their courtroom and corresponding reverberation time in Superior Courts in Georgia.

| jurisdiction | use space type | data domain | r time | user id | rating context type | rating |
|--------------|----------------|-------------|--------|---------|-----------------------|--------|
| State | courtroom | acoustics | 0.64 | ur069 | speech clarity - well | 5 |
| State | courtroom | acoustics | 0.66 | ur019 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.66 | ur020 | speech clarity - well | 7 |
| State | courtroom | acoustics | 0.66 | ur020.1 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.66 | ur021 | speech clarity - well | 4 |
| State | courtroom | acoustics | 0.66 | ur023 | speech clarity - well | 5 |
| State | courtroom | acoustics | 0.66 | ur024 | speech clarity - well | 5 |
| State | courtroom | acoustics | 0.67 | ur073 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.68 | ur103 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.68 | ur104 | speech clarity - well | 4 |
| State | courtroom | acoustics | 0.68 | ur104.1 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.68 | ur107 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.74 | ur145 | speech clarity - well | 6 |

Table 8.10 (continued)

| jurisdiction | use_space_type | data_domain | r_time | user_id | rating_context_type | rating |
|---------------------|-----------------------|--------------------|---------------|----------------|----------------------------|---------------|
| State | courtroom | acoustics | 0.74 | ur146 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.74 | ur146.1 | speech clarity - well | 7 |
| State | courtroom | acoustics | 0.78 | ur038 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.78 | ur041 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.78 | ur041.1 | speech clarity - well | 7 |
| State | courtroom | acoustics | 0.82 | ur115 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.82 | ur116 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.82 | ur117 | speech clarity - well | 5 |
| State | courtroom | acoustics | 0.82 | ur119 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.83 | ur079 | speech clarity - well | 6 |
| State | courtroom | acoustics | 0.85 | ur031 | speech clarity - well | 2 |

8.5 Extract raw data

The support scenario described here relates to situations where an end-user wishes to extract and transfer data to a different system for analyses of one's choosing. Such analyses could include the four scenarios discussed earlier. However, it may be possible that certain end-users have developed their custom analytical tools, and what they need is data to run those tools. This scenario is also true for academic inquiry, where sophisticated statistical analyses, for instance, is sought by the end-user (the content of chapter 9). In other cases the end-user may simply feel more comfortable with a different software or system for data query and extraction.

In essence, this is the most basic form of dissemination of POE data in a raw format for various forms of end use. The steps are identical to those used in the previous sections except for the last step. The end-user runs one or two parallel query (depending on

whether user evaluation data is sought or not) in an identical manner to the ones explained above. The final step involves merging data tables and transferring the data to a separate application.

In the hypothetical scenario described here, the end-user wishes to focus on data pertaining to writing tasks in a courtroom setting. The user believes that four variables influence writing task performance in general, based on literature: the work surface illuminance, task luminance, surrounding luminance and background luminance. By running a query on as-built data, the user is able to extract data on the four environmental variables for each user surveyed in the POE. The parallel query on user evaluation data generates user's rating of their environment's supportiveness to performing writing tasks. Result of the combined query is then transferred to other applications or systems for further works. Table 8.11 shows the result of the query described here. While the query described here pertains to one aspect of the courtroom setting, other aspects could be explored and queried in a similar manner, and query results joined in a single table to perform various statistical and/or mathematical procedures.

Table 8.11: Query output showing (partial) user rating of their environment's supportiveness to writing tasks and corresponding values of environmental parameters.

| user_id | rating_context_type | work_plane_illumination | task_brightness | surround_brightness | background_brightness | rating |
|---------|---------------------|-------------------------|-----------------|---------------------|-----------------------|--------|
| ur056 | writing/typing task | 13.2 | 45.49 | 18 | 2.8 | 6 |
| ur101 | writing/typing task | 14.3 | 42.6 | 39.82 | 4.1 | 5 |
| ur098 | writing/typing task | 14.6 | 48.08 | 12.85 | 4.08 | 3 |
| ur099 | writing/typing task | 14.6 | 42.65 | 34.41 | 3.44 | 7 |
| ur055 | writing/typing task | 17.2 | 68.65 | 22 | 3.82 | 7 |
| ur069 | writing/typing task | 17.6 | 59.43 | 10.57 | 59.64 | 5 |
| ur119 | writing/typing task | 20.6 | 64.45 | 33.63 | 11.38 | 1 |
| ur135 | writing/typing task | 22.6 | 66.87 | 25.51 | 7.06 | |
| ur135.1 | writing/typing task | 22.6 | 66.87 | 25.51 | 7.06 | 6 |
| ur110 | writing/typing task | 23.3 | 78.4 | 54.51 | 9.05 | 6 |
| ur146 | writing/typing task | 24.6 | 85.25 | 25.5 | 52.68 | 6 |
| ur146.1 | writing/typing task | 24.6 | 85.25 | 25.5 | 52.68 | 7 |
| ur115 | writing/typing task | 25.3 | 82.37 | 31.85 | 9 | 5 |
| ur109 | writing/typing task | 26.5 | 83.93 | 54.51 | 13.37 | 5 |
| ur013 | writing/typing task | 27 | 92.06 | 2.28 | 6.68 | 7 |
| ur032 | writing/typing task | 28.2 | 91.72 | 26 | 43.92 | 6 |
| ur059 | writing/typing task | 28.4 | 81.61 | 17 | 7.96 | 7 |
| ur009 | writing/typing task | 28.7 | 98.59 | 2.11 | 8.22 | 6 |

8.6 Predict performance

An additional support mechanism enabled through the previous step is the ability on the part of an end-user to predict the performance of a design based on past evaluation data. The support scenarios described in earlier sections allow investigation of areas of design decisions in isolation. The ability to combine variables in probabilistic models offers a powerful decision support mechanism. Traditionally, research data conducted in controlled settings provided information to the designer (or reviewers of design). Typically, such support mechanisms took the form of guidance documents, codes, standards, or simulation models based on data from controlled settings. As pointed out in the second chapter, the types of data generated through POEs provide more ecologically valid data sets. Further, they are context specific as opposed to the context-less (or less generalizable) data generated from controlled settings. Data from POE studies, thus, promise to provide a supplemental source of information to the end-user. Further, with access to raw data, the end user is offered a wider window for exploration and testing. Moreover, more than one variable could be entered into the analysis, thus providing a powerful source of information generation and testing to the end user.

There are two ways the data is envisaged to support end-users in the design and design review phases. One way is to predict performance of outcomes of design decisions. This is different from academic inquiry where the general focus is on identifying significant associations as opposed to predicting values of outcome variables, although the steps are

mostly identical. Also, academic inquiries usually focus on generalization of study findings, which may not be the objective of a designer or reviewer. For instance, a user may believe that three factors contribute to the symbolic attributes of a courtroom: the size of well, elevation of the bench above well level, and the height of the ceiling. The raw data extraction process explained in the previous section enables the user to extract data on well size, window area, and ceiling height for all (or a section) of the courtrooms in the database. User's ratings on the symbolic characteristics of courtrooms are also extracted for each of the courtrooms. During any testing phase of design development (assuming that courtroom symbolism is agreed upon by the design team as one of the most important desired outcome of the design process) the designer will be able to predict user rating of the courtroom being designed by using the values of the three variables adopted by the designer. The data extraction process will follow steps identical to the ones described in section 8.5, and hence not shown here. By running a multivariate regression on the data the user arrives at the regression equation as shown in equation 8.1. In a hypothetical scenario, the end-user, at a certain phase of the design, arrives at a designed courtroom height of 10 feet, well area of 600 square feet and window area of 200 square feet. By replacing the designed parameter values with the independent variables in the table, the end-user obtains a prediction of user rating on the degree the courtroom would be evaluated as portraying the dignity of law. In this hypothetical scenario, the end-user arrives at a predicted rating of 4.9 (equation 8.1). Whether this is acceptable to the design team, or not, is a separate issue. This support scenario, thus, provides an additional layer of information support, which is context rich.

Equation 8.1:

$$\text{symbolism} = 3.345 + 0.137 (\text{courtroom height}) + 0.001 (\text{well area}) - 0.002 (\text{window area})$$

$$4.9 = 3.345 + 0.137 (10) + 0.001 (600) - 0.002 (200)$$

A second means of support is offered by reversing the use of the same regression equation described above. In this case, the end-user manipulates the value of the independent variables until a desired/acceptable level of user rating is achieved. This could occur either before the initiation of design work, or at any phase during design development. The end-user, subsequently, modifies the design to arrive at targeted values of the design variables that is predicted to provide a desired level of user rating when the building is in use. An example of such a scenario is shown below (equation 8.2) where the values of the three physical variables were manipulated until an acceptable value is reached for each of the parameters as well as the predicted rating. The end-user in this case arrives at a ceiling height of 15 feet, well area of 800 square feet, and window area of 100 square feet, which predicts a user rating of 6.0.

Equation 8.2:

$$6 = 3.345 + 0.137 (15) + 0.001 (800) - 0.002 (100)$$

This mechanism could also be applicable in providing support during design review phases. Design values adopted in alternative designs could be used in regression equations to predict the resultant user rating, for comparison of design alternatives.

Further, the end-users could also run analyses based on their own hypotheses. For instance, the end-user may consider acoustical characteristics of a setting to influence ratings on reading tasks, especially since in courtrooms users are generally multitasked, and perform several tasks simultaneously (such as reading and listening to a witness testimony simultaneously). Such directions of inquiry are, however, more typical to academic settings, which is the domain of processed data outcome. Two major types of processed data outcome are discussed in chapter 9.

8.7 Summary

Six different ways of information support at the programming/ design and design review phases are discussed. The data structure supports querying the data to explore cases, analyze precedence, identify best and worst cases, rate design decisions, extract raw data for use in other applications, and predicting performance of a group of design decisions. The information generated from the data could help decision making in a more informed environment.

An interface was programmed (with external assistance) to demonstrate automated querying of the database. Pictures of a sample interface and result of an example query is included in Appendix 6.3.

Chapter 9

Outcomes from Processed Data

The previous chapter outlined several ways the data could be queried directly by a member of a design or design review team to obtain support information for decision-making. The support information generated are for specific designs, and little formal knowledge would be generated. POEs, however, are context-rich data that offer the scope for generalization, and contribution to theory.

Two main outcomes, through academic research, are described in this chapter. The first constitutes a series of multivariate regressions that begins to contribute to the conventional knowledge on courtrooms as work settings. The second outcome constitutes the development of a small number of KPIs (key performance indicators) that characterize the supportiveness of the courtroom environment to the functions being performed within it. The development of the KPIs is based on the analyses performed in the first section, and, hence, theoretically interrelated. This chapter includes:

9.1 Understanding courtrooms

9.1.1 Visual tasks

9.1.1.1 Influence of lighting and personal variables on visual desktop tasks

9.1.1.2 Influence of lighting and personal variables on visual screen-based tasks

9.1.1.3 Influence of physical and personal variables on near visual tasks

9.1.1.4 Influence of lighting and personal variables on far visual tasks

- 9.1.2 Auditory Tasks
 - 9.1.2.1 Influence of acoustic and personal variables on conversation
 - 9.1.2.2 Influence of acoustic and personal variables on speech privacy
- 9.1.3 Physical factors
 - 9.1.3.1 Well size
 - 9.1.3.2 Well shape
 - 9.1.3.3 Gallery capacity
 - 9.1.3.4 Public waiting area
 - 9.1.3.5 Public waiting capacity
- 9.1.4 Variables associated with courtroom symbolism
- 9.1.5 User satisfaction
- 9.1.6 Summary
- 9.1.7 Multilevel regression models
- 9.2 Indicators of courtroom performance
 - 9.2.1 Developing KPIs
 - 9.2.2 KPI equations based on probability models
 - 9.2.3 KPI values and characteristics
 - 9.2.4 Single number ratings
 - 9.2.5 A worked out example
- 9.3 Summary

9.1 Understanding courtrooms

Courtrooms as work settings, as suggested in the literature review sections, are not widely published in existing literature. The post occupancy evaluations conducted in this study provide a wide range of data to initiate an understanding on courtrooms, and the important variables that influence courtroom task performance. This section on outcomes focuses on the analyses of data gathered through the POE study. Appendix VI, section 6.1 includes several descriptive graphics of the complete dataset.

Data collected in this study relate to four types of parameters. Those include the variables in the: 1) visual domain, 2) auditory domain, 3) physical domain (configuration issues related to size and capacity), and 4) factors assumed to influence courtroom symbolism. The analysis of data will follow the same sequence. Subsequently, issues related to user satisfaction with the setting will be explored. All regression models were tested for influential observations, multicollinearity, and heteroskedasticity. Influential observations were identified using standardized residuals, DFFIT, Cook's D, and DFBETAs. Multicollinearity was tested using Variance Inflation Factor and Condition Index. White's test for heteroskedasticity was conducted on all models. Discussions of such tests are not included in the texts below, unless the tests resulted in re-specification of the original model.

9.1.1 Visual tasks

Seven variables from the list of dependent variables relate to task performance in the visual domain. Those include the user's rating of their environment pertaining to (please see Appendix III, section 3.1 for the actual question asked to measure each variable):

- Reading task (question # 9)
- Screen based task (question # 10)
- Writing/typing task (question # 11)
- Examining evidence (question # 12)
- Observing faces in well (question # 13)
- Observing faces in gallery (question # 14)
- Sightline obstructions (question # 22)

The first step in the analysis was to identify any smaller number of underlying variables that might explain the seven variables. Towards that end a principal component analysis of the seven variables was performed. Result of the principal component analysis, using varimax rotation, is presented in table 9.1. The total variance explained by the two components is 70.96%.

Table 9.1: Rotated component matrix of variables related to visual tasks.

| | Component | |
|------------------------|-------------|--------------|
| | 1 | 2 |
| Reading Task | .773 | .267 |
| Reading from screen | .861 | .165 |
| Writing/typing task | .833 | .166 |
| Examine evidence | .883 | .299 |
| Observe faces-well | .217 | .813 |
| Observe faces-gallery | .489 | .606 |
| Sightline obstructions | -.116 | -.782 |

A closer study of the two components makes it obvious that the first four variables contribute mostly to the first component, and the last three variables to the second component. The two components also have intuitive appeal. The first component relates to variables associated with tasks that are performed on the desktop. The second component relates more to tasks that are generally not desktop related, and are performed across the courtroom, such as observing the face of the witness or potential jurors, and obstructions of sightlines caused owing to courtroom furniture and/or people. Creation of two variables out of the seven observed variables is supported by the analysis.

Typically two methods of reduction are available. Typically the factor scores of the rotated components are saved as values of the new variables and subsequent analysis performed on the new variables (Hamilton, 1992). Alternately, researchers aggregate the scores of the observed variables to derive values for the new variables. The later method was adopted owing to the fact that it makes more intuitive sense to the design profession (the study objective is to create a design decision support mechanism, and it is assumed that the second approach would be better comprehensible as compared to the first). Two new variables were created. The first four observed variables were combined by

calculating their (simple) arithmetic average and named vis_near (for near visual tasks, or those related to desktop tasks). The later three observed variables were combined in a similar fashion to create the last variable vis_far (for far visual tasks, or those involving visual performance across the courtroom).

Several types of as-built data were collected during the site visits of the courtrooms. As discussed earlier, the justification for collecting those data were driven by current understanding on visual task performance in published literature. The data collected from site includes those related to, among others, illuminance, brightness or luminance ratios, a surrogate definition of glare, provision of natural light, viewing distance, user's age, user's gender, and user's role. In addition, some physical (configuration) variables were also assumed to influence visual task performance, such as the work surface area. Study of the influence of environmental and physical variables was conducted through four separate analyses. The first analysis focused on the lighting variables as well as individual/personal variables. The second analysis also focused on the lighting variables, but those hypothesized to influence screen-based tasks. The third step involved the physical variables. The final model includes variables hypothesized to influence far visual tasks.

9.1.1.1 Influence of lighting and personal variables on visual desktop tasks

In this analysis, near visual tasks (vis_near) was regressed on lighting and personal variables. In addition, it was hypothesized that the effect caused by the newness of

facilities which, in turn, influence users' evaluation of their environment, might also be influential, since some of the courtrooms visited were newly constructed and renovated.

Table 9.2 lists the variables included in the analysis:

Table 9.2: List of lighting variables included in the regression model involving near visual tasks.

| Variable Name | Expanded Name | Details |
|---------------|--|--|
| work_ill | work surface illuminance | Illuminance as measured on work surface |
| task_bkg | task to background luminance ratio | Ratio of task luminance to background luminance from user's location |
| task_sur | task to surrounding luminance ratio | Ratio of task luminance to surrounding luminance from user's location |
| bkg_sur | background:surrounding luminance ratio | Ratio of background luminance to surrounding luminance from user's location |
| max_task | ratio of maximum luminance in the field of vision : task luminance | A surrogate measure for glare. Luminance of only the largest and brightest source in the field of vision was measured. The ratio of that value to the task luminance was used as a variable. |
| window_a | total area of windows | Total area of all windows in the courtroom. |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.3: Model summary for regression involving near visual tasks (sample size: 81).

| R | R ² | Adjusted R ² | F | Significance |
|-------|----------------|-------------------------|-------|--------------|
| 0.744 | 0.554 | 0.467 | 6.395 | 0.000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.4: Predicted parameter estimates for regression involving near visual tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 8.514 | | 10.298 | .000*** |
| work_ill | .006 | .115 | 1.044 | .300 |
| task_bkg | .035 | .197 | 1.711 | .092+ |
| task_sur | -.010 | -.136 | -1.029 | .307 |
| bkgr_sur | .024 | .051 | .378 | .706 |
| max_task | .006 | .107 | 1.051 | .297 |
| window_a | .001 | .193 | 1.902 | .061+ |
| Age | -.035 | -.313 | -3.077 | .003** |
| gender | -.421 | -.178 | -1.728 | .089+ |
| occupied | -.235 | -.777 | -7.241 | .000*** |
| role_1 | -.417 | -.159 | -1.334 | .187 |
| role_2 | -.670 | -.234 | -2.015 | .048* |
| role_3 | -.641 | -.224 | -1.751 | .084+ |
| role_4 | .749 | .139 | 1.509 | .136 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.3, and 9.4 summarize the result of the analysis. The model is significant, with an adjusted R² value of 0.467. None of the lighting variables are significant at 0.05 level.

The only significant coefficients at 0.05 level are the age, number of years of occupation, and the dummy variable for reporter.

Age as an important factor has been studied extensively in past research, and the current study further confirms it. The dependant measure here is not actual performance, but the

user's assessment of the work environment about its supportiveness to the kind of tasks they perform. From that viewpoint age as a significant factor suggests that the user's age might influence the way they rate their work environment. Everything else being equal, as the age increase the ratings would decrease. This suggests that task performance requirements for older users are different from the younger ones.

The second significant variable of interest is the reporter. The result suggests that the requirements of a reporter for performing near visual tasks are significantly different from the others. Everything else being equal, the rating of a reporter of the environment would be significantly different from the other courtroom users. Ratings of reporters would be about 0.67 units less (on the 7-point scale) from the ratings of judges. The near visual task of a reporter is indeed very different from the rest of the courtroom users, and the result only underscores the fact that reporters should be treated as a unique user group.

The most influential of the significant findings is the numbers of years of occupation. This variable was included in the model to look for the 'halo' effect associated with newly built settings. The magnitude of the influence of this variable is of greater interest here. At 0.777 beta weight, this variable is contributing most to explaining the variability in the model. The result suggests that the age of the courtroom (new or old) has a significant influence on the way courtroom users rate their environment. As the courtrooms get older, the ratings would get lower, everything else being equal.

Considering the low number of cases (courtrooms studied and users sampled) in this study it may make sense to look at the variables whose parameter estimates are below the 95% but above 90% confidence level. It may be possible that with larger samples some of these coefficients would turn out to be significant. Further, considering the low risks associated with the subject matter of the current study, it may not be risky to look at estimates that are within 0.1 p value. Four variables satisfy the reduced confidence criteria. The first one is a lighting variable, and is the ratio of the task luminance to the background luminance. This finding supports the numerous controlled studies that assert that it is not the illuminance, but the contrast between the task and the background that is of greater importance. The finding suggests that larger contrast produce better ratings, everything else being equal. In turn, it suggests that the material, color and other properties of the desktop needs greater attention during design process.

The window area is the second variable of interest. It addresses two factors discussed in literature. One pertains to the color rendering of the lighting scheme. Researchers have argued that light fixtures with spectral distribution closer to daylight are better for human performance and satisfaction (chapter 5). In the absence of proper instruments to measure the color temperature during site visits, the window area was introduced as a surrogate measure. Courtrooms with windows would introduce daylight into interior spaces, and hence bring the color rendering closer to daylight. The findings suggest that more naturalistic spectral qualities are evaluated better. The second area this surrogate variable addresses is contact with exterior. Studies in school and office settings have suggested that exterior contact might be beneficial to performance. The finding here suggest that the

same might be true in courtroom settings. Day light and/or exterior views provided by windows positively influence the user's evaluation of their setting to conduct near visual tasks.

Gender is yet another area that has been extensively studied in earlier research. The current findings only partially support such studies. The result suggests that the ratings of male users would be less than ratings of female users, everything else being equal. Why males expect or demand more out of their courtroom work environment is the pertinent question arising out of this finding.

The last variable of interest is the dummy variable for attorneys. Like reporters, the attorneys also seem to be rating their environment different from the other users. While every user surveyed in this study perform quite unique tasks, the reporters and attorneys seem to be different from the rest as far as their expectations from the designed environment is concerned. The finding suggests that the attorney's ratings would be lower by 0.64 units on the 7-point scale as compared to the judge, everything else being equal.

The possibility of insignificance of illuminance is also discussed in earlier studies. First, beyond a certain value for illuminance, it ceases to be of any importance to desk-based tasks (see chapter 5). Second, field studies indicate that, in general, values of illuminance in work settings have gone substantially up in the past century, and the range available today is within the reasonable limits to support performance. In this study the range of

illuminance is 13.2 FTC to 155.3 FTC, with a mean of 46.35 FTC. 46.35 may be a good level of illuminance to support most tasks. None of the other lighting parameter estimates show up as significant.

Within the sample, the relative influence (beta weights) of different lighting variables provides a different idea about environmental impact on visual tasks. The most influential (discussed above), is the ratio of task to background luminance, followed by the window area. Task to surrounding luminance ratio is the third most influential. The direction of the association is, however, negative (in contrast to the task to background luminance ratio). Users prefer higher contrast between task and background, but lesser contrast between task and surrounding. This makes intuitive sense in a field situation. As opposed to controlled experiments on lighting where the users perform only one type of task at a time, courtroom users perform multiple visual tasks simultaneously. Such tasks include desktop tasks as well as tasks across the courtroom, such as observing faces. Large contrast between the task and surrounding brightness would be stressful when switching between the desktop task and facial observation tasks. The task to surrounding luminance ratio is followed by task illuminance, ahead of the surrogate measure for glare and the contrast between background and the surrounding. The importance of the contrast between background and surrounding would be an area needing further attention in subsequent studies. The analysis here, however, did not include screen-based tasks, which are increasing in use in modern courtrooms.

9.1.1.2 Influence of lighting and personal variables on visual screen-based tasks

In this analysis, near visual tasks (vis_near) was regressed on lighting and personal variables, but for screen-based task. As before, it was hypothesized that the ‘halo’ effect caused by new facilities would constitute an influential variable (which, in turn, influence users’ evaluation of their environment). Table 9.5 lists the variables included in the analysis:

Table 9.5: List of screen-based lighting variables included in the regression model involving near visual tasks.

| Variable Name | Expanded Name | Details |
|---------------|--|--|
| scrn_ill | screen illuminance | Illuminance measured on the screen/monitor plane |
| srn_bkgr | screen luminance : background luminance | Ratio of screen luminance to the background luminance |
| srn_surr | screen luminance : surrounding luminance | Ratio of screen luminance to surrounding luminance |
| bkgr_sur | background:surrounding luminance ratio | Ratio of background luminance to surrounding luminance from user’s location |
| max_task | ratio of maximum luminance in the field of vision : task luminance | A surrogate measure for glare. Luminance of only the largest and brightest source in the field of vision was measured. The ratio of that value to the task luminance was used as a variable. |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.6: Model summary for regression involving near visual screen tasks (sample size: 81).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .720 | .519 | .434 | 6.110 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.7: Predicted parameter estimates for regression involving Near Visual screen-based tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 9.863 | | 10.831 | .000*** |
| scrn_ill | -.025 | -.126 | -1.181 | .242 |
| srn_bkgr | .006 | .000 | .002 | .999 |
| srn_surr | .100 | .010 | .062 | .951 |
| bkgr_sur | -.049 | -.099 | -1.016 | .313 |
| max_task | .005 | .078 | .843 | .402 |
| age | -.033 | -.288 | -2.643 | .010** |
| gender | -.604 | -.248 | -2.343 | .022* |
| occupied | -.248 | -.720 | -7.227 | .000*** |
| role_1 | -.715 | -.267 | -2.174 | .033* |
| role_2 | -.690 | -.233 | -1.968 | .053+ |
| role_3 | -.867 | -.279 | -2.128 | .037* |
| role_4 | .189 | .038 | .407 | .686 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.6, and 9.7 summarize the results of the analysis. The model as a whole is significant. The adjusted R² value of the model can be considered as high at 0.434.

Among the variables in the model, those of primary interest are the lighting variables.

Surprisingly, none of the estimated parameters of the lighting variables are significant.

However, within the sample, the relative weights of the variables (beta weight) suggest that screen illuminance contributes most to the model, followed by the background to

surrounding luminance ratio. The point to note is that the relative weights of the same or similar variables change depending on whether the focus is on screen-based task or other desktop tasks. A possible reason could be the predominant direction of view. In most screen-based tasks (dealing with monitors), the direction of view is upwards as compared to reading or writing tasks. The field of vision in the former includes more of the background and surrounding as compared to the latter. Thus, the background to surrounding luminance ratio turns out to be of greater weight in screen-based tasks. The same could be argued about the surrogate measure for glare. Owing to a relatively upward direction of view in screen-based tasks, glare becomes more influential as compared to tasks involving reading and writing. The analysis suggests that background to surrounding contrast, and glare are more influential in screen-based tasks as compared to other desktop tasks.

Parameter estimates that are significant also provide valuable information. User's age is significant, and the direction of association is negative, suggesting that everything else being equal, older people would rate their environment lower in supporting screen-based tasks as compared to younger people. Similarly, the result suggests that male users would rate lower as compared to female users. Both of these phenomena were also true for other types of near visual tasks. The variable that once again shows up as significant with the largest influence on the model is 'occupied' (the number of years since construction or last renovation), suggesting that newer courtrooms would result in higher ratings as compared to older courtrooms, everything else being equal. The influence of the age of

the environment over how users evaluate their work setting seems to be true for all types of near visual tasks.

Among tasks types (represented through difference in role), ratings provided by the deputies and attorneys are significantly different from the judge. If the degree of confidence is lowered to 0.1 level, the reporter's rating, once again, is different from the judge. All three parameter estimates are negative, suggesting that the ratings would be lower than those of the judge, everything else being equal. More studies/data is required to hypothesize as to why the different classes of users in the courtroom are rating differently. This, however, suggests that the user groups are far from homogeneous, and greater involvement of the different user groups in the design process would lead to more supportive environments. Finally, a caveat about the findings related to this model. Not all courtrooms visited had monitors on the desktops. Presumably, many users carry their own laptops to work, which were not present during the site visits. There is, thus, an inconsistency between the number of as-built data collected from visits and the number of users who responded to questions on screen-based tasks. The results should be handled with caution. This is evident in some results that are not expected, such as the surrogate measure for glare bearing a positive association with user ratings. There are three possible explanations. First, the surrogate measure adopted is invalid. Second, inconsistency between the number of user rating data and as-built data may be producing un-interpretable results. Third, parts of the relationship may not be linear. In any case, this section of analysis should be treated with caution.

9.1.1.3 Influence of physical and personal variables on near visual tasks

Most published literature on visual tasks deal solely with lighting variables. Ergonomics studies have looked into other areas such as distance from monitor, viewing angle, or height of keyboard. It is also possible that the amount of desktop surface available for conducting visual tasks (reading, writing, etc.) may also influence ones rating of the environment, especially in a multi-tasking situation. In this analysis, near visual tasks (vis_near) was regressed on physical and personal variables. As in the previous models it was hypothesized that ‘occupied’ would be an influential variable. Table 9.8 lists the variables included in the analysis:

Table 9.8: List of physical variables included in the regression model involving near visual tasks.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| work_len | work surface length | Length of work surface as measured on site. |
| work_dep | work surface depth | Depth of work surface as measured on site. |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.9: Model summary for regression involving physical variables and near visual tasks (sample size: 81).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|--------|--------------|
| .760 | .577 | .523 | 10.757 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.10: Predicted parameter estimates for regression involving physical variables and near visual tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 6.985 | | 7.248 | .000*** |
| work_len | .044 | .153 | 1.349 | .181 |
| work_dep | 1.036 | .373 | 2.791 | .007** |
| age | -.043 | -.396 | -4.057 | .000*** |
| gender | -.512 | -.214 | -2.311 | .024* |
| occupied | -.210 | -.685 | -7.859 | .000*** |
| role_1 | -.346 | -.132 | -1.016 | .313 |
| role_2 | -.379 | -.131 | -1.069 | .289 |
| role_3 | -1.474 | -.485 | -2.816 | .006** |
| role_4 | .989 | .202 | 2.188 | .032* |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.9 and 9.10 summarize the findings of the analysis. The model as a whole is significant with an adjusted R² value of 0.523, indicating a high strength of association. The work surface areas available for conducting visual tasks appear to be important variables of the work setting.

Between the two physical variables in the model, the work surface depth is significant where as the work surface length is not. The mean depth of work surfaces among the elements studied is 2.3 feet. A possible explanation is that this depth may not be

appropriate, and courtroom users need deeper work surfaces. This may be partly explained by the increasing number of people using laptops and computers to conduct everyday business. The direction of association is positive, suggesting that with increase in depth there would be a corresponding increase in user rating.

Once again, user's age and gender appear as significant contributing variables. With higher age there would be a corresponding decrease in rating. Similarly, rating of male users would be lower than those of female users, everything else remaining equal. Yet another variable that continues to be significant and most influential is 'occupied' (the number of years of occupancy). With increase in the age of courtrooms there would be corresponding decrease in ratings, everything else remaining the same.

Two of the work characteristics variables (reflected in user role) show significant differences from those of the judges, in ratings. The ratings provided by attorneys and security staffs are significantly different from those of the judges, the attorneys on the negative side and the security on the positive side. This has intuitive appeal, since the security staffs do not conduct much desktop related tasks and may find any facility useful. The attorney, on the other hand, may need larger work surfaces than those provided currently, and hence the lower rating.

9.1.1.4 Influence of lighting and personal variables on far visual tasks

Separate sets of variables were presumed to influence far visual tasks, as opposed to near visual tasks. A major type of far visual task is observing faces in the well (during all times) and the gallery areas (mostly during jury selection). Accordingly, and based on literature (chapter 4 and 5), the following variables were assumed to influence ratings on far visual tasks:

- Light direction and shadows – as captured in horizontal:vertical illuminance ratio.
- Surrounding:Ceiling luminance ratio.
- Viewing distance – as captured in the courtroom area (larger courtrooms would have larger distance between courtroom elements).

In addition, the age of the user was also assumed to influence user's rating on far visual tasks. Further, user role was included in the model since there could be some differences between the user types in terms of the intensity or gravity of the far visual tasks they perform, although the task characteristics (facial observation) are essentially same.

Gender is not included since differences based on gender are not intuitive for far visual tasks, as well as not discussed in lighting literature. In view of the considerable influence the duration of occupation (occupied) had on ratings of near visual tasks, it was included in the model. Table 9.11 lists the variables included in the model.

Table 9.11: List of variables included in the regression model involving far visual tasks.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| hor_verw | horizontal to vertical illuminance ratio in the well | Ratio of illuminance as measured in the horizontal and vertical plane at each user's location. |
| hor_verg | horizontal to vertical illuminance ratio in the gallery | Ratio of illuminance as measured in the horizontal and vertical plane in the gallery seating area. |
| surr_cei | surrounding: ceiling luminance ratio | Ratio of luminance of the surrounding and the ceiling at each user's location. |
| age | user's age | Age of user responding to the questionnaire. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| cr_area | courtroom area | Area of courtroom as measured on site. |
| sight_ob | % of sightline obstructed | Proportion of all people in the well area to where the sightlines are blocked from the user location (reported in percentage). |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.12: Model summary for regression involving far visual tasks (sample size: 81).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .495 | .245 | .125 | 2.035 | 0.038* |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.13: Predicted parameter estimates for regression involving far visual tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 5.768 | | 9.701 | .000*** |
| hor_verw | -.227 | -.306 | -2.687 | .009** |
| hor_verg | .088 | .094 | .749 | .456 |
| surr_cei | .058 | .258 | 1.710 | .092+ |
| age | -.014 | -.249 | -1.797 | .077+ |
| occupied | .000 | .002 | .011 | .991 |
| cr_area | 6.428E-05 | .067 | .539 | .592 |
| sight_ob | -.007 | -.085 | -.705 | .483 |
| role_1 | -.032 | -.023 | -.160 | .874 |
| role_2 | -.398 | -.253 | -1.889 | .063+ |
| role_3 | .084 | .055 | .348 | .729 |
| role_4 | .442 | .189 | 1.519 | .133 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Findings of the analysis are summarized in tables 9.12 and 9.13. The model as a whole is significant at 0.05 p value, with an adjusted R^2 value of 0.125, indicating a weaker association.

Two of the variables, however, deserve attention. The only parameter estimate significant at 0.05 level is the ratio of horizontal to vertical illuminance in the well area. It is negatively associated with user evaluation. The result suggests that higher contrast between horizontal and vertical illuminance would have a corresponding decrease in user ratings related to far visual tasks, or more specifically facial observation tasks. This is true in practical situations where down light ceiling fixtures provide high level of illuminance on the horizontal plane while illuminances on the vertical plane remain low, or not considered in design. For instance, the U.S. Courts Design Guide (AOUSC, 1998) recommendations on courtroom lighting only includes horizontal illuminance levels, for

different elements in the courtroom. The problem associated with the ratio of horizontal to vertical illuminance is related to the discussions in chapter 5 on the role of cast shadows in facial recognition. Although courtroom tasks involve more than just facial recognition, shadows created through inadequate lighting conditions could lead to difficulties in visual task performance.

The second variable of interest is ‘occupied’ (number of years of occupation since construction or last renovation). It was a significant contributing variable in near visual tasks, but is insignificant in far visual tasks, although the direction of association remains the same. Its relative weight (beta coefficient) is one of the least in the model. In contrast, in the previous models, this factor stood out as the one explaining most of the variability in the models. What could explain such a phenomena? A possible explanation is that users consider their immediate work environment (their desk and immediate vicinity) more important as compared to the general environment. Thus, if the immediate environment is newer it affects rating on tasks performed within it, as opposed to far visual tasks that are performed across elements or functional zones. Whether this assumption holds remains to be tested with the subsequent analyses.

Courtroom area, a variable representing distance between locations in a courtroom, did not show up as significant. This could be possibly owing to the fact that most courtrooms surveyed were of reasonable sizes (not so large as to affect visual performance), thus not affecting visual performance. Age and gender, similarly, are not influential variables for

far visual tasks in courtrooms. Finally, there appears to be little difference between role types so far as facial observation tasks are concerned.

If the significance level is relaxed to 0.1 p level, three other variables deserve attention. First, the surrounding to ceiling luminance ratio is positively associated with far visual tasks. This suggests that higher surrounding luminance or lower ceiling luminance would lead to better ratings. This fits well with findings related to horizontal to vertical illuminance ratio. Low vertical illuminance should correlate with low vertical luminance, and it appears that for facial observation tasks users need a more balanced luminous environment. The second variable of interest is the reporter (Role 2). Of all the users types, the reporters are significantly different from the judge. This may relate to the reporter's need to read lip movements, which is probably more difficult than any other facial observation tasks. Finally, the user's age is significant at 0.1 significance level, which follows the pattern observed in other visual tasks. Interestingly, sightline obstructions did not show up as a significant factor in far visual tasks.

9.1.2 Auditory tasks

There are seven dependent variables in the database that relate to task performance in the auditory domain (please see Appendix III, section 3.1 for the actual questions asked to measure the variables).

- Speech loudness – well (question # 15)
- Speech clarity – well (question # 16)

- Speech loudness – gallery (question # 17)
- Speech clarity – gallery (question # 18)
- Speech privacy – others (question # 19)
- Speech privacy – self (question # 20)
- Disturbance from movement (question # 21)

The first step in the analysis was to identify any smaller number of underlying variables that might explain the seven variables. Towards that end a principal component analysis of the seven variables was performed. Result of the principal component analysis, using varimax rotation, is presented in table 9.14. The analysis, after varimax rotation suggested two components:

Table 9.14: Rotated component matrix of variables related to auditory tasks.

| | Component | |
|---------------------------|-------------|-------------|
| | 1 | 2 |
| Loudness-well | .892 | .278 |
| Clarity-well | .892 | .309 |
| Loudness-gallery | .947 | .139 |
| Clarity-gall | .923 | .169 |
| Privacy others | .325 | .837 |
| Privacy self | .121 | .906 |
| Disturbance from movement | -.146 | -.630 |

A closer look at the components suggests that the last variable – disturbance from movement – does not intuitively fit into any of the two components. The first component appears to be related more to speech clarity and audibility, while the second component deals more with speech privacy. As a result, it was decided that disturbance from

movement does not fit into any of the two groups, and may not make any valuable contribution to the analysis.

The last variable was subsequently withdrawn from analysis, and a second principal component analysis was conducted using only the first six dependant variables. Table 9.15 shows the components of the second analysis after varimax rotation, with the two components explaining 89.18% of total variance.

Table 9.15: Rotated component matrix of variables related to auditory tasks – result of the second principal component analysis.

| | Component | |
|------------------|-------------|-------------|
| | 1 | 2 |
| Loudness-well | .892 | .276 |
| Clarity-well | .899 | .282 |
| Loudness-gallery | .941 | .153 |
| Clarity-gall | .925 | .155 |
| Privacy others | .321 | .888 |
| Privacy self | .123 | .947 |

In the second model the proportion of variance explained by the two components improved over the first model. Similar to the case of variables in the visual domain, the factor scores of the components were not used for subsequent analysis. Rather, the two sets of variables were combined and scores recomputed using the arithmetic average of the original data. The first four variables were renamed as conversation (or speech and listening task), and the last two were renamed as privacy.

Independent variables measured in the POE study of courtrooms are the following (see chapter 5 for details on variable selection based on literature, in the auditory domain):

- Reverberation time
- Ambient Noise level
- Visual cue – sightlines
- Age
- Gender

Further, it could be argued that characteristics of tasks performed by different users might influence their ratings of their work setting. Hence, role was included in the regression models. Finally, occupied (years of occupation) was found to be an influential variable in performance of near visual tasks, and it was considered essential to include that variable in analysis in the auditory domain.

9.1.2.1 Influence of acoustic and personal variables over conversation

In this analysis, conversational auditory task (conv) was regressed on sound and personal variables. In addition, it was also hypothesized that the ‘halo’ effect caused by new facilities, which, in turn, influence users’ evaluation of their environment, might also be influential. Table 9.16 lists the variables included in the analysis.

Table 9.16: List of variables included in the regression model involving conversation tasks.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| r_time | reverberation time - mean of RT 250,500, and 1000 Hz | Mean value of reverberation time measured at 250, 500, and 1000 Hz. |
| nc_lvl | background noise NC rating | NC rating arrived at from recorded sound pressure level between 63 and 8000 Hz |
| sight_ob | % of sightline obstructed | Proportion of all people in the well area to where the sightlines are blocked from the user location (reported in percentage). |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.17: Model summary for regression involving conversation tasks (sample size: 79).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .667 | .445 | .364 | 5.457 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.18: Predicted parameter estimates for regression involving conversation tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 10.107 | | .575 | .000*** |
| r_time | -1.077 | -.194 | -2.026 | .047* |
| nc_lvl | -.079 | -.170 | -1.692 | .095+ |
| sight_ob | -.049 | -.285 | -2.609 | .011* |
| occupied | -.101 | -.247 | -2.425 | .018* |
| age | -.016 | -.133 | -1.165 | .248 |
| gender | -.136 | -.052 | -.456 | .650 |
| role_1 | -.076 | -.026 | -.182 | .856 |
| role_2 | -1.342 | -.417 | -3.251 | .002** |
| role_3 | .279 | .087 | .609 | .545 |
| role_4 | .300 | .061 | .563 | .575 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.17 and 9.18 summarize the results of the analysis. The model as a whole is significant with a reasonably robust value of 0.364 for adjusted R^2 . It means that the model explains 36% of the variability in the dependent variable.

Four of the parameter estimates are significant at 0.05 level in the model. The first variable of interest is the reverberation time. That reverberation time has showed up as significant confirms findings in earlier studies that reverberation time influence the clarity of speech. If the degree of confidence were relaxed to 0.1 p value (or probably with larger sample size), the background noise level also show up as an influential variable. Both of these confirm findings in earlier studies where the reverberation time and background noise level were considered to influence speech conditions. There is one difference, however. Based on earlier studies (chapter 5), it is commonly believed that the background noise level is more influential than reverberation time – that changes in

reverberation time do not impact speech/ listening conditions as much as changes in background noise level. This does not appear to be true in this sample. Both show up as negatively associated with user ratings, which is meaningful. Higher reverberation time, as well as background noise level, should be associated with lower rating. The reverberation time is, however, more influential in comparison to background noise level. One possible explanation is offered here. Other studies were mostly conducted in classroom or office settings. Such settings generally have high background noise levels. Courtrooms are generally low-noise environments, other than sound transmitted from external sources (16-28 dB recorded). Moreover, judges have greater control over noise within courtrooms as compared to teachers in a classroom, or employers in offices. This is one area where courtrooms show up as different from other comparable work settings.

Another significant factor relates to sightline obstructions. Sightlines are generally believed to influence visual tasks, although it was not a significant factor in far visual tasks. However, it appears to significantly influence auditory tasks. Visual cues for speech comprehension have long been known to be an important factor. In American courtrooms, visual cue as a contributing factor has increased in importance as the demographic profile of the society has changed significantly over the past century. Increasing number of people in courtrooms are non-English speaking. Accented English is also very common. In such a social situation, it seem to be essential that a clear line of sight be maintained between parties for better speech comprehension. It is notable that sightline obstruction has more influence as compared to reverberation time or

background noise on auditory tasks. The negative association is also logical, since larger sightline obstructions should be associated with lower rating.

The number of years of occupancy since construction/ renovation reappears as a significant variable. The negative association with user ratings is once again intuitive. What needs to be investigated is why it appears as a significant variable in some models, yet insignificant in others.

Age and gender do not show up as significant. A possible explanation is that modern sound reinforcement technology has made it possible for good listening conditions to be created. That is true for most task characteristics with one exception. As discussed in chapter 4, reporters even in the most modern courtrooms face a major problem.

Moreover, of all the role types in a courtroom, reporters perform the most critical listening tasks. The focus is on accurate reporting of case proceedings. The results of this analysis supports the exploratory work reported in chapter 4. Among the role types, the reporters are significantly different from the judges, everything else remaining the same. Moreover, the association is negative, meaning that reporters are expected to rate their environment lower.

9.1.2.2 Influence of acoustic and personal variables on speech privacy

Having obtained a better understanding on the conversational aspect of courtroom functioning, the question arises about aspects of speech privacy. How do the acoustic

factors affect speech privacy in courtrooms, where, in many circumstances, it is considered extremely important? In this analysis the association between privacy (priv) and sound and personal variables was investigated. In addition, it was also hypothesized that the ‘halo’ effect caused by new facilities, which, in turn, influence users’ evaluation of their environment, might also be influential. The only variable excluded was sightline obstructions, since its inclusion does not have any justifications based on theory. Table 9.19 lists the variables included in the analysis:

Table 9.19: List of variables included in the regression model involving speech privacy.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| r_time | reverberation time - mean of RT 250,500, and 1000 Hz | Mean value of reverberation time measured at 250, 500, and 1000 Hz. |
| nc_lvl | background noise NC rating | NC rating arrived at from recorded sound pressure level between 63 and 8000 Hz |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.20: Model summary for regression involving speech privacy (sample size: 78).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .548 | .301 | .208 | 3.249 | .002** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.21: Predicted parameter estimates for regression involving speech privacy.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 7.283 | | 4.616 | .000*** |
| r_time | 1.004 | .157 | 1.465 | .148 |
| nc_lvl | -.097 | -.189 | -1.799 | .076+ |
| occupied | -.186 | -.440 | -4.134 | .000*** |
| age | -.006 | -.041 | -.320 | .750 |
| gender | -.374 | -.124 | -.977 | .332 |
| role_1 | .649 | .201 | 1.360 | .178 |
| role_2 | .335 | .095 | .632 | .529 |
| role_3 | -.330 | -.087 | -.542 | .590 |
| role_4 | 1.120 | .145 | 1.324 | .190 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.20 and 9.21 summarize the results of the analysis. The model is significant with an adjusted R² value of 0.208, indicating a moderate association.

Two phenomena of interest are suggested in the results. Considering a reduced level of confidence at 0.1 p value (or larger sample), background noise appears to be an influential variable for speech privacy. This confirms to earlier findings described in the literature. Within the sample, the relative importance of reverberation time and background noise has switched between conversational needs and privacy needs. For conversation reverberation time was more influential, where as for privacy background

noise is more influential. The finding of interest, however, is the negative association between background noise level and privacy. Conventional wisdom suggests that background noise can be used to mask speech in work settings, for speech privacy. In such a context, higher level of background noise (up to certain limit) should be associated with higher user rating. The negative association between background noise and user rating is the finding of interest. There is one possible explanation. In new courtrooms, use of electronic sound masking systems enables (also perceptually) speech privacy. However, older courtrooms do not have such systems. Many of the courtrooms measured in this study (especially state courtrooms) are older and do not have sound masking systems. Further, older courtrooms receive transmitted sound from external sources (the noise generation is not restricted to the courtrooms). In such a context, it is possible that with higher level of background noise users raise their voice for conversation. As a result, there could be a perceived, or actual, reduction of speech privacy.

The second variable of interest is the duration of occupation, which once again shows up as a significant variable with the largest relative influence. Insignificant parameters for age and gender could have the same explanation as for the analysis for conversation. Finally, the insignificant parameter estimates for role types suggest that speech privacy may be equally important to all parties in the courtroom.

9.1.3 Physical factors

Unlike the variables associated with tasks performed in the visual and auditory domains, which were supported by existing theoretical knowledge, physical configuration of courtrooms (particularly sizes, shapes, capacities, locations, adjacencies, etc.) are topics not widely studied. The exploratory study conducted at the beginning of this study was intended to provide some initial insight on courtrooms and important physical variables in courtrooms that might influence the efficiency at which justice delivery processes are conducted. Based on interviews and observations, it was reported, earlier, that several physical variables constitute important variables influencing courtroom operations. Those include:

- well length and width,
- shape of well,
- gallery seating capacity,
- public waiting area,
- public waiting capacity,
- location of bench,
- location of witness box, and
- configuration of the jury box

Questions on element locations were subsequently removed from the questionnaire for reasons explained in chapter 6. This section deals with five dimensions of physical configuration of courtrooms. The purpose is exploratory, and providing support for some

of the assumptions discussed in chapter 4 (based on the interviews and observations) is intended. The five aspects explored are (please see Appendix I for the exact question asked to measure the variables):

- well size (Question # 1)
- well shape (Question # 2)
- gallery seating capacity (Question # 3)
- public waiting area (Question # 5)
- public waiting capacity (Question # 6)

9.1.3.1 Well size

Well size, as assumed earlier, influence how smoothly the proceedings are conducted, particularly during jury selection and multiple defendant trials. Further, it should influence the way attorneys present their case, particularly the way they portray and perform through their body language. Well length and well width were both included in the analysis. In addition, the user's age, gender and role were included to see if any variability exists. The number of years of occupancy was also included to see if the possible halo effect is also influential in user's rating of the courtroom physical dimensions. Table 9.22 provides a list of variables included in the analysis:

Table 9.22: List of variables included in the regression model involving well size.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| well_len | well length | Length of well as measured on site |
| well_wid | well width | Width of well as measured on site |
| age | user's age | Age of user responding to the questionnaire. |
| gender | user's gender | Gender of user responding to the questionnaire. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.23: Model summary for regression involving well size (sample size: 79).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .741 | .550 | .491 | 9.352 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.24: Predicted parameter estimates for regression involving well size.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 1.549 | | 1.183 | .241 |
| well_len | .076 | .317 | 3.112 | .003** |
| well_wid | .052 | .217 | 2.469 | .016* |
| age | .010 | .064 | .612 | .542 |
| gender | -.840 | -.248 | -2.482 | .015* |
| occupied | -.011 | -.027 | -.264 | .793 |
| role_1 | -.246 | -.067 | -.587 | .559 |
| role_2 | .095 | .024 | .212 | .833 |
| role_3 | -2.206 | -.510 | -3.923 | .000*** |
| role_4 | -.601 | -.057 | -.681 | .498 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.23 and 9.24 summarize the results of the analysis. The model is significant with an adjusted R^2 of 0.491, indicating a strong relationship.

The parameter estimates that show up as significant include both the well length and the well width. Well length provides the flexibility for multiple defendant trials, and well width influence the physical configuration of the jury box. Well length, however, has a greater influence on user ratings as compared to well width, as the result show. This suggests that the number of litigant tables that can be accommodated in the well has a greater influence on user ratings as compared to the configuration of the jury box (principally the number of tiers). At the federal level, not all courtrooms are used for multi defendant trials. But at the state level, most Superior Courts courtrooms encounter situations where more than one pair of litigant parties need to be accommodated within the well, simultaneously. Mean well length of state courtrooms in the database is 25 feet, which is less than the mean for federal courtrooms at 40 feet. Further, a large proportion

of courtrooms in the corpus are state courts courtrooms, and that might explain why courtroom length is more influential as compared to courtroom width, although both are significant. Both variables bear a positive association with user rating, indicating that larger well are rated better.

A second variable of interest is the user gender. As observed in most analysis above, the ratings of male users are significantly lower than ratings of female users. Finally, among the user role types, ratings of the attorney are significantly different. This is logical, since, well dimensions affect the task of the attorneys the most (among all user types in the study). Beside the security staff, the attorneys are the only group that move within the well as part of their work description, and are most affected by available space in the well. This is indicated by the fact that the ratings of the attorneys would be about 2 points less than that of the judges everything else being equal.

9.1.3.2 Well shape

Discussions with various stakeholders of courthouses had suggested that well shape could influence courtroom operations. Long, wide, square, and circular well are supposed to provide different types of support to phases of courtroom proceedings (see chapter 4). Instead of the categorical classification of well shape, a more objective classification was adopted – the ratio of the well width to well length. Higher the ratio, wider would be the courtroom. User's age and gender were not included since there were no grounds to believe that those variables would influence user's decision. User's role was included to

see if any variability exists among the courtroom users. The number of years of occupancy was also included to see if the possible halo effect is also influential in user's rating of the courtroom physical dimensions. Table 9.25 provides a list of variables included in the analysis:

Table 9.25: List of variables included in the regression model involving well shape.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| well_shp | Shape of well | Ratio of well width to well length |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.26: Model summary for regression involving well shape (sample size: 83).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .419 | .175 | .110 | 2.693 | .020* |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.27: Predicted parameter estimates for regression involving well shape.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 5.702 | | 7.392 | .000*** |
| well_shp | .882 | .132 | 1.045 | .299 |
| occupied | -.041 | -.138 | -1.052 | .296 |
| role_1 | -.804 | -.290 | -2.262 | .027* |
| role_2 | .124 | .041 | .324 | .747 |
| role_3 | -.962 | -.317 | -2.511 | .014* |
| role_4 | -.452 | -.095 | -.806 | .423 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.26 and 9.27 summarize the results of the analysis. The model is significant, with an adjusted R^2 value of 0.110, which indicates a weak association.

The parameter estimates reflect the weak association. The actual measured well shape is not significantly associated with user's rating of well shape. Nor is the number of years of occupation a significantly influential variable. Rather, the difference between the ratings of judges, deputies and attorneys seem to explain the variability. Both court deputies and attorneys are likely to provide ratings less than those of the judges. As to why the deputies or the attorneys would have a different view about shape of the well is not known, and is an area warranting further studies.

Within the sample, well shape has a positive association with user ratings, indicating that wider wells would be associated with higher ratings. Most of the courtrooms visited are trial courtrooms, and this supports the earlier assertion (chapter 4) that wider or square courtrooms are better suited for trial, where as longer courtrooms are better suited for

other phases of a case. On the whole, however, well shape appears to be a less important factor as compared to actual dimensions of the well.

9.1.3.3 Gallery capacity

Total number of people galleries can hold is, as proposed earlier, crucial to two phases of any case; pretrial phases, and jury selection phases (chapter 4). Accordingly, gallery capacity was analyzed as a physical configuration variable. In addition, the number of years of occupation and user role was included for similar reason as the earlier analyses.

Table 9.28 provides a list of variables included in the analysis:

Table 9.28: List of variables included in the regression model involving gallery capacity.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| gal_seat | gallery seating capacity | Number of seats in the spectator gallery |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.29: Model summary for regression involving gallery capacity (sample size: 80).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .628 | .394 | .344 | 7.913 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.30: Predicted parameter estimates for regression involving gallery capacity.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 5.203 | | 13.501 | .000*** |
| gal_seat | .016 | .693 | 5.144 | .000*** |
| occupied | -.182 | -.514 | -3.766 | .000*** |
| role_1 | -.567 | -.160 | -1.446 | .152 |
| role_2 | -.149 | -.039 | -.358 | .722 |
| role_3 | -1.544 | -.408 | -3.740 | .000*** |
| role_4 | -1.121 | -.079 | -.798 | .427 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.29 and 9.30 summarize the results of the analysis. The model is significant with an adjusted R^2 value of 0.344, indicating a moderately strong association.

Among the significant parameter estimates, actual number of seats in the gallery has a positive association with user rating, indicating that more gallery seats would be associated with higher rating. This supports the findings from the earlier exploratory study that gallery seating capacity could be an influential variable. The number of years of occupancy is also significantly associated with user ratings of the gallery. The only role type that is significantly different from the judges, in ratings, is role 3 (attorneys). This finding is logical, since attorneys are the people most affected by gallery capacities. Lawyers/attorneys are affected by seating capacity in the earlier/pretrial phases of a case as well as during scheduling and bond hearings. They are also affected during jury selection phase where appropriate number of seats in the gallery could greatly enhance courtroom operations. It is, thus, not surprising that the ratings of the attorneys would be

different. The negative association suggests that the attorneys' rating would be significantly lower than the judges' rating.

9.1.3.4 Public waiting area

The role of the public waiting area outside the courtrooms should also be important during pretrial and jury selection phases (chapter 4). The actual area (clearly demarcated) allocated for public waiting space was included in the analysis. In addition, the number of years of occupation and user's role were included for the same justification as the earlier analyses. Table 9.31 lists the variables included in the analysis:

Table 9.31: List of variables included in the regression model involving public waiting area.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| wait_are | public waiting area | Actual area allocated to dedicated public waiting space. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.32: Model summary for regression involving public waiting area (sample size: 82).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .525 | .276 | .218 | 4.768 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.33: Predicted parameter estimates for regression involving public waiting area.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 5.520 | | 9.915 | .000*** |
| wait are | .006 | .236 | 2.350 | .021* |
| occupied | -.225 | -.326 | -3.252 | .002** |
| role 1 | -.227 | -.048 | -.405 | .687 |
| role 2 | -.760 | -.144 | -1.223 | .225 |
| role 3 | -1.571 | -.304 | -2.576 | .012* |
| role 4 | .606 | .031 | .311 | .757 |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.32 and 9.33 summarize the results of the analysis. The model as a whole is significant with an adjusted R² value of 0.218, indicating a moderately strong association.

Among the significant parameter estimates the actual floor area allocated for dedicated public waiting space has a significant positive association with user's rating. This indicates that larger waiting areas for public would be associated with higher ratings from users. Once again, the number of years of occupation has a significant influence over user ratings, and exerts greater influence in comparison to the public waiting area. The only role type that is significantly different from the judges is, once again, role 3 (attorneys). This could have an explanation similar to that of gallery seating capacity. The role type

that is most affected by provision of public waiting is the attorney, both during early pretrial phases of a case and during jury selection phase. It is, thus, not surprising that the attorneys would rate this aspect of the courtroom's physical configuration differently. The parameter estimate suggests that the attorneys' rating would be significantly different from, and less than, that of the judges.

9.1.3.5 Public waiting capacity

During the exploratory phases of this study it was asserted that merely providing dedicated waiting spaces for the public would not suffice, and necessary amenities including seats should influence how efficiently the cases are conducted, particularly at the early/pretrial phases, and the jury selection phase (chapter 4). The actual seating capacity for the public was included in the analysis. In addition, the number of years of occupation and user's role were included for the same justification as the earlier analyses. Table 9.34 provides a list of variables included in the analysis:

Table 9.34: List of variables included in the regression model involving public waiting capacity.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| wait_cap | Public waiting seating capacity | Actual number of seats provided for public waiting. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| role_1 | dummy variable for "Role" = deputy | Using judge as the reference. |
| role_2 | dummy variable for "Role" = reporter | Using judge as the reference. |
| role_3 | dummy variable for "Role" = attorney | Using judge as the reference. |
| role_4 | dummy variable for "Role" = security | Using judge as the reference. |

Table 9.35: Model summary for regression involving public waiting capacity (sample size: 83).

| R | R ² | Adjusted R ² | F | Significance |
|---|----------------|-------------------------|-------|--------------|
| .532 | .283 | .226 | 4.999 | .000*** |
| (***) (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)) | | | | |

Table 9.36: Predicted parameter estimates for regression involving public waiting capacity.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|---|----------------------------|--------------------------|--------|--------------|
| (Constant) | 5.264 | | 8.900 | .000*** |
| wait_cap | .019 | .067 | .655 | .515 |
| occupied | -.177 | -.328 | -3.229 | .002** |
| role_1 | .134 | .029 | .247 | .805 |
| role_2 | -.662 | -.134 | -1.148 | .254 |
| role_3 | -1.983 | -.401 | -3.487 | .001*** |
| role_4 | .447 | .034 | .336 | .738 |
| (***) (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)) | | | | |

Tables 9.35 and 9.36 summarize the results of this analysis. The model as a whole is significant with a R² value of 0.226.

Among the significant parameter estimates, the actual number of seats provided for public waiting is not significant. However, the number of years of occupancy bears a significant relationship with user ratings. Among the role types, the attorney's rating, once again, is significantly different from those of the judges. The explanation is same as for the waiting areas and gallery capacities. The attorneys, as a role type, are most affected by the provision of seats in waiting areas, and hence the significance. The

parameter estimate is negative, indicating that everything else being equal, the attorneys' rating would be less by approximately 2 points (on the seven point scale) from the judge.

9.1.4 Variables associated with courtroom symbolism

Two of the dependant variables relate to courtroom symbolism issues. One user response was specifically about light, and the other about courtroom geometry. A correlation analysis suggested that the two variables are highly correlated (Pearson Correlation = 0.639, significant at 0.01 level). Following logic similar to the ones adopted for visual and auditory tasks, the two variables were combined into a single variable named 'symbol'.

A number of independent variables were hypothesized to influence symbolic attributes of a courtroom. Courtroom shape was considered important since rectangular, square, circular and other shapes convey different meanings (as discussed in chapter 4). Courtroom area and height were considered important considering that, traditionally, designers have manipulated scale to provide the feeling of awe and dignity. Similarly, gallery seating capacity was included as a factor. In light of newer studies that show natural light as a factor influencing symbolism, window area was included in the analysis. It is also believed that the elevation of the bench is of symbolic importance, as well as the height of the edge-lip. Further, based on the discussions in chapter 4, the elevation of the jury box (first row) and number of jury tiers were added to the variable list. Some of the lighting parameters were considered important for portraying symbolic

values and were included. Finally, the number of years of occupation (occupied) was added considering its significant influence on many of the dependent variables discussed in previous sections. Table 9.37 lists the variables included in the analysis.

Table 9.37: List of variables included in the regression model involving courtroom symbolism.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| cr_shape | courtroom shape | The ratio of the length to the width of the courtroom |
| cr_high | courtroom height | Height of courtroom as measured on site |
| cr_area | courtroom area | Area of courtroom as measured from plans |
| window_a | window area | Total area of windows in the courtroom |
| gal_seat | gallery seating capacity | Number of seats in the spectator gallery |
| bench_fl | bench floor elevation | Elevation of bench floor above well |
| bench_ed | bench edge-lip height | Height of edge-lip above well level |
| jury_el | jury elevation | Elevation of the first row of the jury box above well level |
| jury_tie | jury tier | Number of tiers in the jury box |
| hor_verw | horizontal to vertical illuminance ratio in the well | Ratio of illuminance as measured in the horizontal and vertical plane at each user's location. |
| hor_verg | horizontal to vertical illuminance ratio in the gallery | Ratio of illuminance as measured in the horizontal and vertical plane in the gallery seating area. |
| surr_cei | surrounding: ceiling luminance ratio | Ratio of luminance of the surrounding and the ceiling at each user's location. |
| surr_flo | surrounding: floor luminance ratio | Ratio of luminance of the surrounding and the visible floor at each user's location. |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |

The model, with the above variables, displayed evidence of multicollinearity. Within the sample, larger courtrooms are generally associated with higher ceiling, and more window area (if windows were present). Similarly, higher bench elevations also have higher edge-lips around the bench. Owing to such problems (and in order to avoid multicollinearity) the variables were combined into chunks by combining their standardized scores. The new variables are outlined in table 9.38. Redefinition of the variables eliminated the multicollinearity.

Table 9.38: List of redefined variables included in the regression model involving courtroom symbolism.

| Variable Name | Expanded Name | Details |
|---------------|---|--|
| cr_shape | courtroom shape | The ratio of the length to the width of the courtroom |
| cr_symb | courtroom symbolic factors | Combined variable representing courtroom area, height and window area. |
| ben_symb | bench symbolic factors | Combined variable representing bench floor elevation and edge-lip height. |
| jur_symb | jury symbolic factors | Combined variable representing jury floor elevation and number of rows. |
| gal_seat | gallery seating capacity | Number of seats in the spectator gallery |
| hor_verw | horizontal to vertical illuminance ratio in the well | Ratio of illuminance as measured in the horizontal and vertical plane at each user's location. |
| hor_verg | horizontal to vertical illuminance ratio in the gallery | Ratio of illuminance as measured in the horizontal and vertical plane in the gallery seating area. |
| surr_cei | surrounding: ceiling luminance ratio | Ratio of luminance of the surrounding and the ceiling at each user's location. |
| surr_flo | surrounding: floor luminance ratio | Ratio of luminance of the surrounding and the floor at each user's location. |

Table 9.39: Model summary for regression involving courtroom symbolism (sample size:81).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|-------|--------------|
| .638 | .406 | .331 | 5.402 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.40: Predicted parameter estimates for regression involving courtroom symbolism.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | 7.306 | | 8.170 | .000*** |
| cr_shape | -1.798 | -.432 | -3.333 | .001*** |
| cr_symb | .987 | 1.026 | 5.554 | .000*** |
| ben_symb | .115 | .106 | 1.013 | .314 |
| jur_symb | .008 | .002 | .021 | .983 |
| gal_seat | -.011 | -.885 | -3.461 | .001*** |
| hor_verw | .423 | .408 | 3.696 | .000*** |
| hor_verg | .183 | .134 | .728 | .469 |
| surr_cei | -.016 | -.092 | -.463 | .645 |
| surr_flo | .117 | .545 | 2.391 | .019* |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.39 and 9.40 summarize the results of the analysis. The model as a whole is significant with an adjusted R² value of 0.331, indicating a moderately strong association. Five of the parameter estimates are significant at the 0.05 p level, and provide valuable insight. The courtroom shape is significant and negatively associated with symbolism. It implies that the users associate wider courtrooms with larger symbolic values. This corresponds with the findings on well shape. Users ranked wider well higher. The two findings are complementary. Wider courtrooms (and, hence, well) serve the symbolic needs better. This is in contrast to the fact that most courtrooms are actually long

courtrooms. The second variable of interest is courtroom area, height, and window area. It has a positive association with symbolism. It confirms conventional wisdom that larger courtrooms with high ceiling portray symbolic values better in courtroom settings. Window area was not studied earlier, and provides new information. Users associate larger window with better symbolic values. A similar conclusion could not be drawn, however, regarding gallery seats. Larger galleries are rated lower for symbolic function, which is in contrast to courtroom area and height. Users, it appears, prefer larger well area and smaller gallery area for portraying symbolic values. Finally, two of the lighting parameters are significant. The first is the ratio of horizontal to vertical illuminance in the well area (but not in the gallery). This suggests that higher visual clarity (as opposed to visual fields with cast shadows) is rated better for symbolic functions. This is also reflected in the ratio of surrounding to floor luminance. Users rate higher surrounding luminance (which is a function of vertical illuminance) higher in symbolic values. The most influential of the five variables, however, is `cr_symb` (the variable representing courtroom area, ceiling height, and window area). These three physical variables constitute the most important factors influencing symbolic attributes of courtroom settings. It is also noteworthy that neither the bench attributes nor the jury box attributes are significantly associated with courtroom symbolism, as measured.

9.1.5 User satisfaction

Most POEs focus on user satisfaction with various aspects of the environment.

Satisfaction, however, is a complex construct. Parts of user satisfaction with their work

environment, it could be argued, are derived from how well the built environment supports the task they perform. Many other factors could influence how satisfied a person is with his/her environment. The model below (figure 9.1) captures the essence of the relationship.

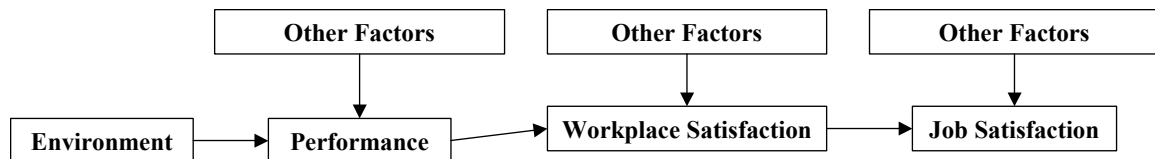


Figure 9.1: The larger theoretical framework within which the current study is viewed.

The focus of this section of the analysis is to see how much of the users' evaluation of environmental support, for the task they perform, contribute to their overall satisfaction with the courtroom. Another issue of interest is to see which aspects of the courtroom setting contribute more to satisfaction. Towards that objective, the user's ratings of the environment were considered in eight correlated chunks arrived at through principal component analysis. Five of the correlated chunks have already been discussed before.

They are:

- Near visual tasks: vis_near
- Far visual tasks: vis_far
- Conversation: conv
- Privacy: priv
- Symbolism: symbol

The physical-configuration variables have been dealt with separately (as separate variables) before. To arrive at smaller number of underlying variables explaining most of the variability, a factor analysis of the dependant variables dealing with physical dimensions was conducted. The result of the first principal component analysis with varimax rotation is shown in Table 9.41.

Table 9.41: Rotated component matrix of variables related to physical configuration.

| | Component |
|--------------------------|------------------|
| | 1 |
| Well Size | .836 |
| Well Shape | .858 |
| Gallery Capacity | .700 |
| # of jurybox tiers | .775 |
| Public waiting area size | .846 |
| Public waiting capacity | .828 |
| Work surface area | .707 |
| Work station storage | .733 |

There was a lack of intuitiveness in the resulting component. Clearly well characteristics and public waiting should not share any commonalities to be correlated. Conceptually there are three separate chunks of data in the eight variables: one set dealing with courtroom, a second with public waiting, and the third with the workstation. To see if this would hold, the principal component analysis was repeated, but with two changes. First, the number of jury tiers was taken out of analysis since it did not fit in intuitively with any of the chunks. Second, three components were requested from the analysis. The result of the second analysis is shown below:

Table 9.42: Rotated component matrix of variables related to physical configuration – result of the second principal component analysis.

| | Component | | |
|--------------------------|-------------|-------------|-------------|
| | 1 | 2 | 3 |
| Well Size | .822 | .316 | .262 |
| Well Shape | .769 | .400 | .271 |
| Gallery Capacity | .854 | .170 | .129 |
| Public waiting area size | .303 | .859 | .299 |
| Public waiting capacity | .331 | .883 | .216 |
| Work surface area | .248 | .166 | .894 |
| Work station storage | .183 | .303 | .865 |

On closer examination it would be obvious that the first component contributes more to the well size, well shape, and gallery capacity – courtroom variables. The second component contributes more to public waiting size and public waiting capacity. Finally, the third component contributes more to workstation size and storage area. The three dimensions, combined, explain 86.56% of total variance. Combining the variable chunks described above created three new variables. The three combined variables were added to the five mentioned above to be included in the analysis of user satisfaction. Table 9.43 provides a list of variables included in the analysis:

Table 9.43: List of variables included in the regression model involving overall satisfaction.

| Variable Name | Details |
|---------------|--|
| vis_near | Combined variables for near visual tasks |
| vis_far | Combined variables for far visual tasks |
| conv | Combined variables for conversation tasks |
| priv | Combined variables for speech privacy |
| symbol | Combined variables related to courtroom symbolism |
| courtroom | Combined variables related to courtroom dimensions |
| public | Combined variables related to public area dimensions |
| area_sto | Combined variables related to workstation size and storage area. |

Table 9.44: Model summary for regression involving overall satisfaction (sample size: 80).

| R | R ² | Adjusted R ² | F | Significance |
|------|----------------|-------------------------|--------|--------------|
| .935 | .874 | .860 | 61.754 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.45: Predicted parameter estimates for regression involving overall satisfaction.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|------------|----------------------------|--------------------------|--------|--------------|
| (Constant) | -2.701 | | -5.088 | .000*** |
| vis_near | .257 | .190 | 2.985 | .004** |
| vis_far | .204 | .104 | 2.090 | .040* |
| conv | .021 | .020 | .319 | .751 |
| priv | .011 | .013 | .212 | .833 |
| symbol | .726 | .573 | 9.020 | .000*** |
| courtroom | .100 | .102 | 1.622 | .109 |
| public | .006 | .009 | .136 | .892 |
| area_sto | .203 | .235 | 4.252 | .000*** |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Tables 9.44 and 9.45 summarize the results of the analysis. The model is significant with an adjusted R² of 0.860 indicating a very strong association. The model essentially tries to capture the relationship between user's evaluation of the extent to which the designed environment supports the task they perform on one hand, and their satisfaction with the courtroom, on the other. The findings suggest that the supportiveness of the environment to the tasks one performs in the workplace contributes considerably to one's satisfaction with courtrooms.

Four parameter estimates are significant. Users' evaluations of their environment's supportiveness to both the visual tasks are significant. Similarly, evaluations related to the extent the courtrooms portrayed appropriate symbolism is significant, and so also are their evaluations of the supportiveness of the immediate work environment (workstation, storage). The largest influence is from evaluations of courtroom symbolism, followed by those of workstation area and storage, and finally near and far visual tasks. Symbolism may be playing an influential role in courtrooms owing to the high symbolic value of such work settings. It would be interesting to see if symbolism plays any role in other types of work settings (offices, schools). The second major observation that could be suggested is that users' evaluation of the supportiveness of their immediate workstation to the tasks they perform on it appear to drive satisfaction more than their evaluations of the general physical characteristics of the workplace. Further, users' assessment of the auditory environment did not show up as significant contributors to satisfaction. On the whole, it may not be erroneous to observe that one's assessment of the immediate physical

environment along with ones perception about the symbolic importance of the workplace in general contribute more to ones satisfaction as compared to other factors. Finally, since the number of years of occupation (occupy) had such a large influence on user's evaluation of the supportiveness of their work setting, it can be assumed that it has a major influence on satisfaction too.

9.1.6 Summary

The series of analyses conducted in this chapter provides some valuable insight into courtrooms as work settings. Table 9.46 summarizes the findings along with overall model significance, value of adjusted R^2 , and significant parameter estimates.

Several conclusions could be drawn from table 9.46. Considering parameter estimates significant at the 0.05 level, very few of the lighting variables are significantly influencing near visual (desk top) tasks. Rather, the work surface depth constitutes a significant factor in the visual tasks domain. In far visual tasks (observing faces across the well) the ratio of the horizontal to vertical illumination is a significant influence on user ratings. Interestingly, sightline obstructions do not affect ratings on visual tasks. Rather, it influences conversation tasks (speech comprehension). The other variable associated with speech comprehension is reverberation time (and not background noise). This finding suggests that courtrooms as work settings are different (in the auditory domain) from other settings, such as offices and schools, where background noise is reported to be the more influential factor. Further, none of the acoustics factors influence

user ratings on speech privacy. This may be owing to electronic sound masking systems that are common in courtrooms. Among physical variables well size is significant, but not well shape. Both gallery and public waiting area are significant in influencing user ratings.

A noteworthy finding relates to the variable ‘role’. It could be argued, based on findings that courtroom users are not a homogeneous group, and significantly differ in task characteristics and ratings. Among the user groups, the attorneys are significantly different from judges in most of the analyses, followed by the reporters and court deputies (with judge as the reference category). This finding should have several implications on issues related to the design process and composition of design teams in courthouse projects. Finally, the variable ‘occupied’ warrants some discussion (number of years of occupation since construction or renovation). It appears significant in all near visual tasks, auditory tasks, and user ratings on gallery and public waiting area. It is not significant in three of the models – far visual tasks (across the well), well area, and well shape. One possible explanation is that users do not distinguish between their workstations and the overall well area, and within the well area users are more focused on their immediate work environment (their desktops and the work associated with their immediate environment). However, outside the well area they do consider the gallery and public waiting area as aggregated entities. Newer courtrooms come with better (more advanced) technology that significantly enhances the support a user gets in performing courtroom tasks, which may partly account for the significant influence ‘occupied’ has on user’s rating of their work environment.

Table 9.46: Summary of regression analyses on courtrooms showing standardized coefficients.

| MODELS | vis_near | vis_near screen | vis_near physical | vis_far | conv | priv | well_size | well_shp | gall_cap | pub_wait | pub_cap | symbolism |
|-------------------------|----------|-----------------|-------------------|---------|-------|--------|-----------|----------|----------|----------|---------|-----------|
| Model significance | .0*** | .0*** | .0*** | .03* | .0*** | .0** | .0*** | .02* | .0*** | .0*** | .0*** | .0*** |
| Adjusted R ² | .46 | .43 | .52 | .12 | .36 | .20 | .49 | .11 | .34 | .21 | .22 | .33 |
| work_ill | .11 | | | | | | | | | | | |
| task_bkg | .19+ | | | | | | | | | | | |
| task_sur | -.13 | | | | | | | | | | | |
| bkgr_sur | .05 | -.09 | | | | | | | | | | |
| max_task | .10 | .07 | | | | | | | | | | |
| window_a | .19+ | | | | | | | | | | | |
| scrn_ill | | -.13 | | | | | | | | | | |
| srn_bkgr | | .00 | | | | | | | | | | |
| srn_surr | | .01 | | | | | | | | | | |
| work_len | | | .15 | | | | | | | | | |
| work_dep | | | .37** | | | | | | | | | |
| hor_verw | | | | -.30** | | | | | | | | .4*** |
| hor_verg | | | | .09 | | | | | | | | .13 |
| surr_cei | | | | .25+ | | | | | | | | -.09 |
| cr_area | | | | .06 | | | | | | | | |
| sight_ob | | | | -.08 | -.28* | | | | | | | |
| r_time | | | | | -.19* | .15 | | | | | | |
| nc_lvl | | | | | -.17+ | -.18+ | | | | | | |
| well_len | | | | | | | .31** | | | | | |
| well_wid | | | | | | | .21* | | | | | |
| well_shp | | | | | | | | .13 | | | | |
| gal_seat | | | | | | | | | .7*** | | | -.8*** |
| wait_are | | | | | | | | | | .23* | | |
| wait_cap | | | | | | | | | | | .06 | |
| cr_shape | | | | | | | | | | | | -.4*** |
| cr_symb | | | | | | | | | | | | 1*** |
| ben_symb | | | | | | | | | | | | .10 |
| jur_symb | | | | | | | | | | | | .002 |
| surr_flo | | | | | | | | | | | | .54* |
| age | -.31** | -.28** | -.4*** | -.24+ | -.13 | -.04 | .06 | | | | | |
| gender | -.17 | -.24* | -.21* | | -.05 | -.12 | -.24* | | | | | |
| role_1 (deputy) | -.15 | -.26* | -.13 | -.02 | -.02 | .20 | -.06 | -.29* | -.16 | -.04 | .02 | |
| role_2 (reporter) | -.23* | -.23+ | -.13 | -.25+ | -.4** | .09 | .02 | .04 | -.03 | -.14 | -.13 | |
| role_3 (attorney) | -.22+ | -.27* | -.5** | .05 | .08 | -.08 | -.5*** | -.31* | -.4*** | -.30* | -.4*** | |
| role_4 (security) | .13 | .038 | .20* | .18 | .06 | .14 | -.05 | -.09 | -.07 | .03 | .03 | |
| occupied | -.8*** | -.7*** | -.7*** | .002 | -.24* | -.4*** | -.02 | -.13 | -.5*** | -.3** | -.3** | |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

A different explanation for influence of ‘occupied’ in the models pertains to ‘halo’ effect. Newer facilities would be rated better irrespective of actual technical performance or spatial provisions only because users perceive newer facilities as better environments. To ascertain whether the phenomenon observed in the analyses relates to the halo effect or to actual difference in performance the courtrooms were divided into two categories: 1) new, and 2) old. New courtrooms were defined as those that were built or renovated within the three years preceding the survey. Old courtrooms were defined as those aged five years or more. There were no courtrooms aged four years. The division resulted with 11 courtrooms described as new, and 14 courtrooms as old (a roughly equal cluster). On one courtroom the age data was not available and, hence, was excluded from the analysis. The mean attribute levels between the two sets were tested for significant difference using t-test for difference. Key statistics from the results of the t-tests are included in the table 9.47. It can be observed that in most courtroom attributes the newer and older courtrooms do not show evidence of significant differences. The only significant differences are evident in four areas. Newer courtrooms have greater task-to-surrounding brightness levels, horizontal-to-vertical illuminance ratios in public galleries, well areas, and work surface areas. Newer courtrooms had lesser level of relative humidity. Owing to the lack of evidence suggesting significant difference, it could be argued that the influence suggested by the variable occupied in the regression models are probably owing to the halo effect or some other factor/s.

Table 9.47: Difference in mean parameter values between newer and older courtrooms.

| Courtroom Parameter | Mean, newer courtrooms | Mean, older courtrooms | Difference in mean values | Significant t-statistics |
|---|------------------------|------------------------|---------------------------|--------------------------|
| Illuminance | 51.2 | 44.47 | 6.73 | 0.750 |
| Task-to-background luminance ratio | 9.9 | 8.28 | 1.63 | 0.627 |
| Task-to-surrounding luminance ratio | 23.63 | 5.06 | 18.57 | 3.332** |
| Background-to-surrounding luminance ratio | 2.94 | 1.66 | 1.28 | 1.444 |
| Horizontal-to-vertical illuminance in well | 2.44 | 2.48 | -0.03 | -0.115 |
| Horizontal-to-vertical illuminance in gallery | 2.24 | 1.71 | 0.53 | 1.796+ |
| Window area | 216.55 | 169.07 | 47.48 | 0.461 |
| Reverberation time | 1.01 | 0.87 | 0.14 | 1.049 |
| Background noise (NC) | 21.59 | 22.07 | -0.48 | -0.34 |
| Courtroom area | 2184.84 | 1827.23 | 357.61 | 1.279 |
| Courtroom height | 16.63 | 13.96 | 2.67 | 1.024 |
| Well area | 1503.57 | 884.33 | 619.24 | 4.467*** |
| Gallery capacity | 80.82 | 120.29 | -39.47 | -1.576 |
| Public waiting area | 72.86 | 39.78 | 33.09 | 0.826 |
| Public waiting capacity | 11.09 | 9.57 | 1.52 | 0.487 |
| Workstation area | 23.83 | 12.03 | 11.80 | 4.707*** |
| Workstation storage | 4.05 | 2.15 | 1.90 | 1.585 |
| Temperature | 70.63 | 69.80 | 0.83 | 0.895 |
| Relative humidity | 47.28 | 51.55 | -4.27 | -1.18+ |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

9.1.7 Multilevel regression models

Data, such as the ones collected in this study, are frequently analyzed using multilevel or hierarchical regression models. It is pointed out in methodological literature (Hox, 2004) that fitting ordinary least square regression (OLS) lines on hierarchical data results in violation of OLS assumption as well as error in results. Data are considered clustered when independent variables are measured at individual levels as well as at one or more

higher levels of aggregation constituting those individuals. Multi-stage cluster sampling also results in clustered data sets. Similarly, longitudinal studies involving multiple observations of the same subjects result in clustered data sets. In such cases, it is asserted that outcome measures could be influenced by attributes at several levels. In this study, the courtrooms constitute the upper level and courtroom users the lower level. It could be argued that the outcome measures are influenced by variables/ attributes at the lower level (individual level attributes) as well as the upper level (courtroom attributes). In other words, the variance of the outcomes could be attributed to both levels of independent variables. It is possible that outcome measurements within clusters could be highly correlated. In such cases, it cannot be assumed that the observations are independent – one of the assumptions of OLS regression. Using OLS regression for clustered data sets involves yet another problem. In truly clustered data sets, the sampling variance of the estimated parameters is large when fitted into OLS models. In such cases, insignificant findings could show up as significant, spuriously, although the parameter estimates remain unbiased. If the data in this study are clustered, some of the significant findings above may actually be insignificant.

Because the data are inherently clustered, multilevel models were estimated with courtroom level variables at the higher level and individual level variables at the lower level. In multilevel models it is assumed that all of the individual level parameters are influenced by each of the courtroom level attributes. Such a design results in interaction terms between each of the variables at the upper level and each variable at lower level. An abstract specification of the model followed in the analyses described here, with just

two variables at the individual level and one at the courtroom level, is shown below (error terms are not shown to keep the representation simple).

Individual level model:

$$(\text{user evaluation}) = b_0 + b_1 (\text{individual variable \#1}) + b_2 (\text{individual variable \#2}) \quad (1)$$

Influence of courtroom level explanatory variable:

$$b_0 = c_0 + c_1 (\text{courtroom variable}) \quad (2)$$

$$b_1 = d_0 + d_1 (\text{courtroom variable}) \quad (3)$$

$$b_2 = e_0 + e_1 (\text{courtroom variable}) \quad (4)$$

Substitution of (2), (3) and (4) in (1) results in:

$$\begin{aligned} (\text{user evaluation}) = & (c_0 + c_1 (\text{courtroom variable})) + (d_0 + d_1 (\text{courtroom variable})) * \\ & (\text{individual variable \#1}) + (e_0 + e_1 (\text{courtroom variable})) * \\ & * (\text{individual variable \#2}) \end{aligned} \quad (5)$$

Simplifying model (5) produces:

$$\begin{aligned} (\text{user evaluation}) = & c_0 + d_0 (\text{individual variable \#1}) + e_0 (\text{individual variable \#2}) + c_1 \\ & (\text{courtroom variable}) + (b_1 * d_1) (\text{individual variable \#1} * \text{courtroom variable}) + (b_2 * e_1) \\ & (\text{individual variable \#2} * \text{courtroom variable}) \end{aligned}$$

↔

$$\begin{aligned} (\text{user evaluation}) = & b_0 + b_1 (\text{individual variable \#1}) + b_2 (\text{individual variable \#2}) + b_3 \\ & (\text{courtroom variable}) + b_4 (\text{individual variable \#1} * \text{courtroom variable}) + b_5 (\text{individual} \\ & \text{variable \#2} * \text{courtroom variable}) \end{aligned}$$

One major requirement of multilevel modeling is a fairly large sample size within each cluster. The sample size within each courtroom in this study is between 3-5 on an average. In order to create a larger sample a simulation was conducted using bootstrapping in resampling statistics (Howell, 2002). A sample of 1000 observations was created, and used in the models. Table 9.48 summarizes the significance of parameter estimates in every model using multilevel regression (the complete model summaries are included in Appendix VI, section 6.2; owing to the large number of interaction terms in the models, those terms are not included in table 9.48).

A comparison of table 9.46 and table 9.48 provides some new insight. In case of true clustered data, it would be expected that some of the significant parameter estimates in OLS models would become insignificant in multilevel models. However, more parameter estimates are significant in the multilevel models as compared to OLS models described in the previous sections. That suggests that clustering is not a problem. Further, the larger number of significant estimates could, partly, be the result of a larger dataset.

The inclusion of interaction terms in the models presents the opportunity to identify potential moderators in courtrooms. A comparison of the R^2 values of the models in table 9.46 with those in table 9.48 shows that the inclusion of interaction terms resulted in

larger R^2 values in many of the models. That is in addition to a large number of interaction terms being significant (see appendix VI, section 6.2). The increases in R^2 values are more in the models involving visual and auditory task performance as outcome variables. That suggests that associations between individual level variables in visual/auditory task performance and users' evaluations of the supportiveness of their work settings are conditional on several attributes of the courtroom. The courtroom attributes (moderators) that are in the models that demonstrated increased R^2 values are listed in table 9.49.

Table 9.48: Summary of multilevel regression analyses on courtrooms showing standardized coefficients.

| MODELS | vis_near | vis_near screen | vis_near physical | vis_far | conv | priv | well_size | well_shp | gall_cap | pub_wait | pub_cap | symbolism |
|-------------------------|----------|-----------------|-------------------|---------|--------|--------|-----------|----------|----------|----------|---------|-----------|
| Model significance | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** | .00*** |
| Adjusted R ² | .65 | .38 | .54 | .51 | .61 | .45 | .61 | .09 | .33 | .21 | .20 | .69 |
| work_ill | .4*** | | | | | | | | | | | |
| task_bkg | .12** | | | | | | | | | | | |
| task_sur | .36** | | | | | | | | | | | |
| bkgr_sur | -.1*** | -.3*** | | | | | | | | | | |
| max_task | .34*** | .12** | | | | | | | | | | |
| window_a | -.5*** | | | | | | | | | | | |
| scrn_ill | | .06 | | | | | | | | | | |
| srn_bkgr | | -.026 | | | | | | | | | | |
| srn_surr | | -.32* | | | | | | | | | | |
| work_len | | | -.9*** | | | | | | | | | |
| work_dep | | | -.02 | | | | | | | | | |
| hor_verw | | | | -.4*** | | | | | | | | .26*** |
| hor_verg | | | | -.11* | | | | | | | | -.4*** |
| surr_cei | | | | 1*** | | | | | | | | 1.3*** |
| cr_area | | | | .18 | | | | | | | | |
| sight_ob | | | | .14** | .74*** | | | | | | | |
| r_time | | | | | 1*** | -.4*** | | | | | | |
| nc_lvl | | | | | -.6*** | -.7*** | | | | | | |
| well_len | | | | | | | .55*** | | | | | |
| well_wid | | | | | | | -.09 | | | | | |
| well_shp | | | | | | | | .21*** | | | | |
| gal_seat | | | | | | | | | .71*** | | | -.06 |
| wait_are | | | | | | | | | | .07 | | |
| wait_cap | | | | | | | | | | | .02 | |
| cr_shape | | | | | | | | | | | | -.9*** |
| cr_symb | | | | | | | | | | | | .44*** |
| ben_symb | | | | | | | | | | | | -.4*** |
| jur_symb | | | | | | | | | | | | -.1*** |
| surr_flo | | | | | | | | | | | | -.1*** |
| age | -.4*** | -.2*** | -.4*** | -.2*** | -.3*** | .003 | .01 | | | | | |
| gender | -.2*** | -.12** | -.1*** | | .02 | .12*** | -.3*** | | | | | |
| role_1 (deputy) | -.04 | -.1*** | -.4*** | -.02 | -.3*** | .26*** | -.1*** | -.06+ | -.07* | -.08* | -.05 | |
| role_2 (reporter) | -.2*** | -.2*** | -.3*** | -.2*** | -.4*** | .33*** | .009 | .02 | -.01 | -.1*** | -.06+ | |
| role_3 (attorney) | -.2*** | -.2*** | -.2*** | .03 | -.2*** | .13** | -.6*** | -.2*** | -.1*** | -.3*** | -.4*** | |
| role_4 (security) | -- | .01 | -- | -- | -- | .31*** | .01 | .05 | .14** | -.1*** | -.07* | |
| occupied | -.7*** | -.5*** | -.3*** | -.6*** | .7*** | -.9*** | .3*** | -.2*** | -.6*** | .04 | -.09* | |

(*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1))

Table 9.49: Potential moderators in courtroom settings.

| Variable Name | Expanded Name | Details |
|----------------------|---|--|
| cr_area | courtroom area | Area of courtroom as measured on site. |
| well_len | well length | Length of well as measured on site |
| well_wid | well width | Width of well as measured on site |
| occupied | appx number of years occupied since const or renovation | Number of years since the courtroom was constructed or last renovated. |
| window_a | total area of windows | Total area of all windows in the courtroom. |
| r_time | reverberation time - mean of RT 250,500, and 1000 Hz | Mean value of reverberation time measured at 250, 500, and 1000 Hz. |
| nc_lvl | background noise NC rating | NC rating arrived at from recorded sound pressure level between 63 and 8000 Hz |

The characteristics of moderator effects in each of the models are not detailed out here to keep the discussions limited to the main focus of this dissertation. An example would help articulate the conditional effects between the two sets of variables. Table 9.50 below lists the estimated parameters for the interaction terms for the first model involving near visual tasks. There are two courtroom level variables in the model – window area (window_a) and years of occupation (occupied). The complete model is included in appendix VI. The model shows that the association between users’ evaluation of their environment’s supportiveness to perform near visual tasks, and as-built factors including illuminance, brightness ratios, and glare are conditional upon the window area in the courtrooms. Similarly, the association between users’ evaluation and personal variables (age, role and gender) are conditional on the window area. Number of years since construction (last renovation) also acts as a moderator between users’ evaluation and illuminance, background-to-surrounding luminance ratio, glare, age and gender, as well

as for the difference between judges, and reporters and attorneys. Consider, for instance, the association between users' ratings (the predicted variable) and two independent variables – user age and occupied. Age is an individual level variable, while occupied is a courtroom level variable. The model suggests that with increase in age there would be a predicted decrease in ratings, everything else being equal. Similarly, with increase in years of occupation (occupied) there would be a predicted decrease in ratings, everything else being equal. The significant interaction term (occupied x age) shows the potential moderator effect between age and user ratings. In other words, higher age groups are predicted to be associated with lower ratings, but the negative association between age and ratings is of greater magnitude in older courtrooms as compared to newer ones.

The analyses discussed so far helped in identifying influential variables and moderators in courtroom settings. Since the outcome variables pertain to task performance in courtrooms, the regression models developed in this section could also be used to develop key performance indicators of courtrooms. The following section details the developments of indicators.

Table 9.50: Estimated parameters for interaction terms for model involving near visual tasks.

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|---------------------|----------------------------|--------------------------|---------|--------------|
| window_a x work_ill | -7.171E-05 | -.261 | -4.042 | .000*** |
| window_a x task_bkg | .000 | -.255 | -6.458 | .000*** |
| window_a x task_sur | .001 | 1.082 | 12.333 | .000*** |
| window_a x bkgr_sur | -.004 | -1.333 | -10.399 | .000*** |
| window_a x max_task | .000 | -.816 | -9.468 | .000*** |
| window_a x age | -.000 | -.287 | -7.014 | .000*** |
| window_a x gender | .001 | .137 | 3.439 | .001*** |
| window_a x role_1 | -.002 | -.166 | -3.484 | .001*** |
| window_a x role_2 | .000 | -.036 | -.553 | .580 |
| window_a x role_3 | -.002 | -.190 | -3.214 | .001*** |
| occupied x work_ill | .002 | .120 | 1.765 | .078+ |
| occupied x task_bkg | -.002 | -.029 | -.451 | .652 |
| occupied x task_sur | -.002 | -.110 | -.978 | .328 |
| occupied x bkgr_sur | -.057 | -.421 | -4.345 | .000*** |
| occupied x max_task | .004 | .759 | 8.621 | .000*** |
| occupied x age | -.008 | -.285 | -7.731 | .000*** |
| occupied x gender | .066 | .141 | 3.300 | .001*** |
| occupied x role_1 | -.028 | -.032 | -.719 | .473 |
| occupied x role_2 | -.149 | -.313 | -4.439 | .000*** |
| occupied x role_3 | .002 | .002 | .041 | .967 |
| occupied x role-4 | -.334 | -.044 | -1.899 | .058+ |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

9.2 Indicators of courtroom performance

The analyses reported in section 9.1 enabled the development of a small number of KPIs (key performance indicators) that captures the (predicted) degree of supportiveness of a designed courtroom (or as-built courtroom) to the tasks performed within it. The first part of this section explains the steps taken in developing the indicators. The second part includes one worked out example.

9.2.1 Developing KPIs

There are several areas in which a courtroom is expected to provide support for task performance. This was amply reflected in the previous discussions. There are a series of tasks in the visual domain as well as in the auditory domain. Further, courtroom physical dimensions also influence the flow of people and materials. There are symbolic issues too. In such a context, it would be very cumbersome for one to compare two or more courtrooms, or assess a single courtroom using the long list of variables discussed so far. It would be advantageous to decision makers (such as design review committee) to arrive at decisions based on a limited set of defined criteria.

The principal component analyses conducted in the previous section provide the first step in creating lesser number of dimensions on which a courtroom could be assessed. It was shown that despite the varied areas on which the users provided ratings (such as reading,

writing and other tasks in the visual domain), many of the rating areas cluster together. In such a scenario, it may be more economical to consider the lesser number of dimensions that explain a larger set of issues on which users provide ratings. In the previous section those dimensions have already been used. The following table lists the dimensions used in the previous analyses, and the corresponding name of indicator that will be used in this section.

Table 9.51: List of courtroom performance indicators.

| Variables from Principal Component Analysis | Performance Indicator | Interpretation |
|---|---|--|
| vis_near | NVT: Near visual task indicator | How well is the courtroom environment predicted to support visual (desktop) tasks? |
| vis_far | FVT: Far visual task indicator | How well is the courtroom environment predicted to support visual tasks across the courtroom? |
| conv | SCI: Speech comprehension indicator | How well is the courtroom environment predicted to support speech comprehension? |
| priv | SPI: Speech Privacy Indicator | How well is the courtroom environment predicted to afford speech privacy? |
| courtrm | CPI: Courtroom physical support indicator | How well is the courtroom's physical attribute predicted to support functions conducted within it? |
| public | PPI: Public physical support indicator | How well is the public waiting area's physical attributes predicted to support functions conducted within the courtroom? |
| area_sto | WPI: Workstation physical support indicator | How well is the physical attribute of courtroom elements predicted to support functions conducted within the courtroom? |
| symbol | CSI: Courtroom symbolism indicator | How well is the courtroom environment predicted to portray appropriate symbolic values. |

In the regression analyses conducted in section 9.1, several variables were hypothesized to influence each of the aggregate measures listed above. In essence, the same list of variables is used for predicting values on each of the indicators, with some minor changes. The changes suggested relate to three issues:

- Inclusion of significant parameter estimates,
- Inclusion of personal variables (age, gender, role), and
- Use of hierarchical models that include interaction terms

The changes suggested could be viewed from the perspectives of policy as well as pragmatism. The first choice listed refers to the use of only the significant variables in the KPI equations as opposed to all hypothesized variables irrespective of their statistical significance. While both perspectives could be argued favorably, depending on the particular end-use of the KPIs, from an academic/ research viewpoint it was considered prudent to include only the significant ones. For demonstration purposes one of the equations will be supplemented with a second variation that includes all variables, for comparison.

A second area of consideration is the question of including or excluding personal variables. In the simple models (the non-hierarchical ones, which is discussed next) exclusion of personal variables would result in averaging out the associations across user attributes. On the other hand, including personal variables, for instance role, would increase the sensitiveness of the KPIs. The KPIs could be developed separately for different users - judges, deputies, reporters, etc. However, the number of KIPs will

increase substantially with the inclusion of each personal variable, with the potential danger that such large numbers of KPIs would become difficult to comprehend at certain level. From a policy perspective, it remains the tasks of the review committee members (or other end users) to decide whether to assess alternative design solutions that optimizes performance for one or more user attributes.

The KPIs could be made even more sensitive by modeling those based on the hierarchical models as opposed to the non-hierarchical ones. The policy question addressed in the previous paragraph holds true for this alternative strategy. In addition, it includes several practical issues. Models with interaction terms are much more difficult to comprehend as compared to non-hierarchical ones. The parameter estimates in the models are based on centered variables (to reduce multi-collinearity), which means the parameters in the models and the t-tests for significance of parameter estimates will be different from models without centered variables. Finally, the end-users of the KPIs will be required to deal with the complexities of using centered variables. As in the previous case, excluding the hierarchical modeling approach would generally average out the associations across user attributes.

While all the options discussed above are feasible, for the purpose of this dissertation user attributes are not included in the models for KPIs. In addition, only significant parameter estimates will be used in the models. For one model, three variations of the model will be included to illustrate the changes to the parameter estimates as user attributes and non-significant variables are included or excluded.

Finally, considering the problems associated with the data on screen-based visual tasks (discussed earlier), such variables will not be included in developing near visual task indicator (with more data, such variables could be factored in with relative ease). Table 9.52 lists each indicator and the corresponding variables that were hypothesized in section 9.1 as predictor variables (excluding user attributes).

Table 9.52: Courtroom KPIs and predictor variables.

| Performance Indicator | Predictor Variables |
|---|---|
| NVT: Near visual task indicator | Task/work illuminance, task:background luminance, task:surrounding luminance, background:surrounding luminance, window area, work surface length, work surface depth, years of occupation. |
| FVT: Far visual task indicator | Horizontal:vertical illuminance (well), horizontal:vertical illuminance (gallery), surrounding:ceiling luminance, courtroom area, % of sightline obstructed, years of occupation. |
| SCI: Speech comprehension indicator | Reverberation time, NC rating, % of sightline obstructed, years of occupation. |
| SPI: Speech Privacy Indicator | Reverberation time, NC rating, years of occupation. |
| CPI: Courtroom physical support indicator | Well length, well width, well shape, gallery capacity, years of occupation. |
| PPI: Public physical support indicator | Public waiting area, public waiting capacity, years of occupation. |
| WPI: Workstation physical support indicator | Work surface length, work surface depth, workstation storage capacity, years of occupation. |
| CSI: Courtroom symbolism indicator | Courtroom shape, standardized aggregation of (courtroom area, courtroom height, window area), standardized aggregation of bench elevation, bench edge-lip height), standardized aggregation of (jury first row elevation, number of jury tiers), gallery seating capacity, horizontal:vertical illuminance (well), horizontal:vertical illuminance (gallery), surrounding:ceiling luminance, surrounding:floor luminance. |

The list includes the same variables included in the regression equations with changes as discussed above. The second step entails building equations so that courtrooms could be measured/represented on each of the KPIs.

9.2.2 KPI equations based on probability models

A rich data set that reflects the profile of the population, generated through POEs, is considered as the starting point to develop a prediction method. For the purpose of this section it is assumed, here, that the sample represents the population of courtrooms in the United States. Larger data sets would provide more accurate prediction equation through regression analysis. Since the list of hypothesized variables was altered for developing KPIs, a separate set of regression analyses was conducted for this section. The analyses include the statistically significant parameter estimates from among the variables listed in table 9.52. The following eight equations include the slope estimates derived from multivariate regression analyses, for each of the KPIs. The equations also include two other variations using significant and insignificant parameters, and user attributes, for comparison purposes. The variant of KPI to use relates to policy-level questions. More detailed equations would result in greater specificity of results. However, in some scenarios of end-use, it is conceivable that less detailed equations (where parameter estimates are averaged out across user attributes) could be helpful, such as in case of a very preliminary design phase.

Equation 9.1a: NVT (near visual task indicator) model with only significant parameter estimates – used in this KPI

$$\text{NVT} = 5.698 + 0.026 (\text{task:background luminance}) + 0.415 (\text{work surface depth}) - 0.183 (\text{years of occupation})$$

Equation 9.1b: model including insignificant parameter estimates but no user attributes

$$\begin{aligned} \text{NVT} = & 5.252 + 0.003 (\text{task illuminance}) + 0.035 (\text{task:background luminance}) - 0.014 \\ & (\text{task:surrounding luminance}) + 0.061 (\text{background:surrounding luminance}) + 0.004 \\ & (\text{max_task}) + 0.000 (\text{window area}) + 0.021 (\text{work surface length}) + 0.452 (\text{work surface} \\ & \text{depth}) - 0.194 (\text{years of occupation}) \end{aligned}$$

Equation 9.1c: model with user attributes

$$\begin{aligned} \text{NVT} = & 6.87 + 0.004 (\text{task illuminance}) + 0.03 (\text{task:background luminance}) - 0.017 \\ & (\text{task:surrounding luminance}) + 0.045 (\text{background:surrounding luminance}) + 0.005 \\ & (\text{max_task}) + 0.001 (\text{window area}) + 0.04 (\text{work surface length}) + 0.85 (\text{work surface} \\ & \text{depth}) - 0.039 (\text{age}) - 0.546 (\text{gender}) - 0.231 (\text{years of occupation}) - 0.332 (\text{deputy}) - \\ & 0.552 (\text{reporter}) - 1.34 (\text{attorney}) + 0.888 (\text{security}) \end{aligned}$$

Equation 9.2a: FVT (far visual task indicator) model with only significant parameter estimates – used in this KPI

$$\begin{aligned} \text{FVT} = & 5.205 - 0.177 (\text{horizontal:vertical illuminance - well}) + 0.049 \\ & (\text{surrounding:ceiling luminance}) - 0.014 (\text{years of occupation}) \end{aligned}$$

Equation 9.2b: model including insignificant parameter estimates but no user attributes

$$\text{FVT} = 5.283 - 0.194 (\text{horizontal:vertical illuminance - well}) + 0.029 (\text{horizontal:vertical illuminance - gallery}) + 0.041 (\text{surrounding:ceiling luminance}) + 0.012 (\text{years of occupation}) - 0.000 (\text{courtroom area}) - 0.004 (\% \text{ sightline obstructed})$$

Equation 9.2c: model with user attributes

$$\text{FVT} = 5.768 - 0.227 (\text{horizontal:vertical illuminance - well}) + 0.088 (\text{horizontal:vertical illuminance - gallery}) + 0.058 (\text{surrounding:ceiling luminance}) - 0.014 (\text{age}) + 0.012 (\text{years of occupation}) - 0.000 (\text{courtroom area}) - 0.007 (\% \text{ sightline obstructed}) - 0.32 (\text{deputy}) - 0.398 (\text{reporter}) + 0.084 (\text{attorney}) + 0.442 (\text{security})$$

Equation 9.3a: SCI (speech comprehension indicator) model with only significant parameter estimates – used in this KPI

$$\text{SCI} = 9.572 - 1.438 (\text{reverberation time}) - 0.09 (\text{background noise}) - 0.044 (\% \text{ sightline obstructed}) - 0.091 (\text{years of occupation})$$

Equation 9.3b: model including insignificant parameter estimates but no user attributes

$$\text{SCI} = 9.572 - 1.438 (\text{reverberation time}) - 0.09 (\text{background noise}) - 0.044 (\% \text{ sightline obstructed}) - 0.091 (\text{years of occupation})$$

Equation 9.3c: model with user attributes

$$\text{SCI} = 10.107 - 1.077 (\text{reverberation time}) - 0.079 (\text{background noise}) - 0.049 (\% \text{ sightline obstructed}) - 0.101 (\text{years of occupation}) - 0.016 (\text{age}) - 0.136 (\text{gender}) - 0.76 (\text{deputy}) - 1.342 (\text{reporter}) + 0.279 (\text{attorney}) + 0.3 (\text{security})$$

Equation 9.4a: SPI (speech Privacy Indicator) model with only significant parameter estimates – used in this KPI

$$\text{SPI} = 7.838 - 0.093 (\text{background noise}) - 0.168 (\text{years of occupation})$$

Equation 9.4b: model including insignificant parameter estimates but no user attributes

$$\text{SPI} = 6.834 + 1.162 (\text{reverberation time}) - 0.095 (\text{background noise}) - 0.167 (\text{years of occupation})$$

Equation 9.4c: model with user attributes

$$\text{SPI} = 7.283 + 1.004 (\text{reverberation time}) - 0.097 (\text{background noise}) - 0.186 (\text{years of occupation}) - 0.006 (\text{age}) - 0.374 (\text{gender}) + 0.649 (\text{deputy}) + 0.335 (\text{reporter}) - 0.33 (\text{attorney}) + 1.12 (\text{security})$$

Equation 9.5a: CPI (courtroom physical support indicator) model with only significant parameter estimates – used in this KPI

$$\text{CPI} = 1.771 + 0.007 (\text{well length}) + 0.027 (\text{well width}) + 0.009 (\text{gallery capacity}) - 0.062 (\text{years of occupation})$$

Equation 9.5b: model including insignificant parameter estimates but no user attributes

$$\text{CPI} = 1.771 + 0.007 (\text{well length}) + 0.027 (\text{well width}) + 0.009 (\text{gallery capacity}) - 0.062 (\text{years of occupation})$$

Equation 9.5c: model with user attributes

$$\begin{aligned} \text{CPI} = & 0.175 + 0.053 (\text{well length}) + 0.098 (\text{well width}) + 4.855 (\text{well shape}) + 0.008 \\ & (\text{gallery capacity}) - 0.083 (\text{years of occupation}) - 0.001 (\text{age}) - 0.595 (\text{gender}) - 0.54 \\ & (\text{deputy}) - 0.301 (\text{reporter}) - 1.808 (\text{attorney}) \end{aligned}$$

Equation 9.6a: PPI (public physical support indicator) model with only significant parameter estimates – used in this KPI

$$\text{PPI} = 4.917 + 0.006 (\text{public waiting area}) - 0.225 (\text{years of occupation})$$

Equation 9.6b: model including insignificant parameter estimates but no user attributes

$$\text{PPI} = 4.947 + 0.006 (\text{public waiting area}) - 0.004 (\text{public waiting capacity}) - 0.226 (\text{years of occupation})$$

Equation 9.6c: model with user attributes

$$\begin{aligned} \text{PPI} = & 5.532 + 0.006 (\text{public waiting area}) - 0.008 (\text{public waiting capacity}) - 0.224 \\ & (\text{years of occupation}) + 0.132 (\text{deputy}) - 0.802 (\text{reporter}) - 1.703 (\text{attorney}) + 0.657 \\ & (\text{security}) \end{aligned}$$

Equation 9.7a: WPI (workstation physical support indicator) model with only significant parameter estimates – used in this KPI

$$\text{WPI} = 6.924 - 0.642 (\text{work surface depth}) - 0.063 (\text{years of occupation})$$

Equation 9.7b: model including insignificant parameter estimates but no user attributes

$$\text{WPI} = 6.267 + 0.069 (\text{work surface length}) - 0.677 (\text{work surface depth}) + 0.058 (\text{work station storage}) - 0.038 (\text{years of occupation})$$

Equation 9.7c: model with user attributes

$$\begin{aligned} \text{WPI} = & 5.689 + 0.045 (\text{work surface length}) - 0.173 (\text{work surface depth}) + 0.028 (\text{work} \\ & \text{station storage}) - 0.045 (\text{years of occupation}) - 0.005 (\text{age}) - 0.309 (\text{gender}) - 0.583 \\ & (\text{deputy}) - 0.287 (\text{reporter}) - 1.407 (\text{attorney}) - 0.624 (\text{security}) \end{aligned}$$

Equation 9.8a: CSI (courtroom symbolism indicator) model with only significant parameter estimates – used in this KPI

$$\begin{aligned} \text{CSI} = & 6.712 - 0.603 (\text{courtroom shape}) + 0.629 (\text{courtroom physical}) - 0.008 (\text{gallery} \\ & \text{capacity}) + 0.27 (\text{horizontal:vertical illuminance} - \text{well}) + 0.023 (\text{surrounding:floor} \\ & \text{luminance}) \end{aligned}$$

Equation 9.8b: model including insignificant parameter estimates but no user attributes

$$\begin{aligned} \text{CSI} = & 7.306 - 1.798 (\text{courtroom shape}) + 0.987 (\text{courtroom physical}) + 0.115 (\text{bench} \\ & \text{physical}) + 0.008 (\text{jury physical}) - 0.011 (\text{gallery capacity}) + 0.423 (\text{horizontal:vertical} \end{aligned}$$

$$\text{illuminance} - \text{well}) + 0.183 (\text{horizontal:vertical illuminance} - \text{gallery}) - 0.016 \\ (\text{surrounding:ceiling luminance}) + 0.117 (\text{surrounding:floor luminance})$$

It is conceivable that the equations could change as more variables are hypothesized to influence user ratings, or with more data more parameter estimates show up as statistically significant. That would take the process back to section 9.1, where scientific studies based on POE data would provide support to hypothesized associations. Also, more number of indicators could be added as more aspects of a courtroom are studied in greater details.

9.2.3 KPI values and characteristics

Assuming that the database has a rich set of representative data of American courtrooms, respective parameter values from a courtroom in the design phase, or an existing courtroom that is not evaluated, could be plugged into the equations above. For instance, if the well length, well width, gallery capacity and years of occupation of any courtroom are known the predicted rating on CPI could be obtained by plugging those values into equation 9.5. Courtrooms in the design stage could also be rated using the equation for CPI and other indicators.

For each of the equations above, the resultant number (predicted rating) would vary between 1 and 7. That is owing to the fact that the user rating scale limits the range between 1 and 7. In all instances, 1 would be the bottom of the rating scale and 7 would

be the top. That would allow a variation between predicted rating from very unsupportive to very supportive environment. Plotting the values of all the KPIs on a single map would provide a visual representation to support decision-making and communication between stakeholders. An example of a hypothetical map is shown in figure 9.2. The bold line shows how a hypothetical courtroom performs on the eight different dimensions created here. The dashed, bold line within it could be the minimum criteria decided by a client or a design review committee. The circles in the background represent levels on the rating scale. The innermost circle represents 1 and the outermost circle represent 7.

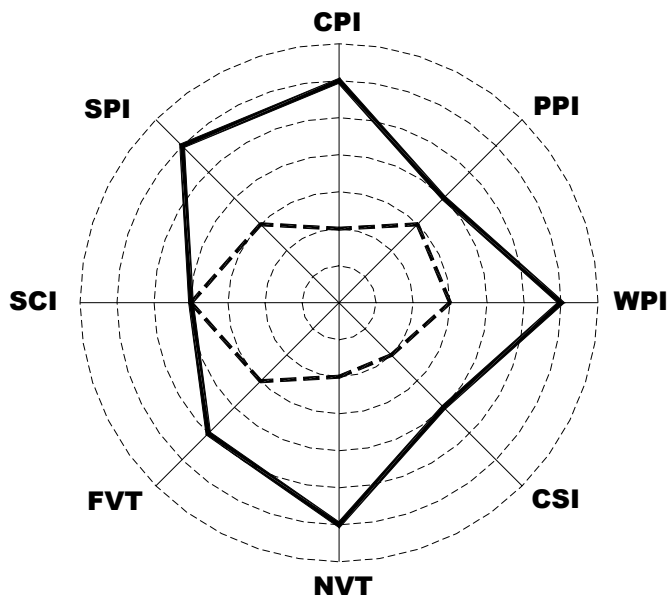


Figure 9.2: A KPI radar map showing a hypothetical courtroom.

In the map developed here all indicators are of equal weight. It is also possible that a certain end-user might consider one or more of the dimensions more important to a project as compared to the others. In such a case the lengths of each dimension could be increased to a desirable value, with corresponding decrease in the values of less important dimensions. As indicated earlier, the maximum value of each dimension would be 7 (or the highest point of the ordinal scale used in a POE). One, two, or more courtrooms could be mapped and assessed together on the eight dimensions. This is in contrast to the long list of variables that were dealt with in data analysis.

9.2.4 Single number ratings

The radar maps are also scaled representations. Thus, the area occupied by each courtroom profile could be calculated. The comparison between two or more courtroom areas would provide a gross estimate of the relative supportiveness of each courtroom for the tasks/functions conducted within it.

The areas however may not be comparable if the number of dimensions/indicators on the radar maps change between cases. A simple way to normalize the number is to divide the area obtained by the maximum area a hypothetical courtroom could occupy on the radar map. The latter number is the area enclosed by a polygon touching the highest rating on each of the dimensions (the perfect case). This ratio would be bounded between 0 and 1. A rating of 1 would mean the absolute best (supportive) case, and zero would be the absolute worst (unsupportive) case. It is, once again, left to the end-user to determine the

points within this boundary where the courtroom is understood to meet the minimum and other desired levels. The normalized single number rating is immune to the number of dimensions on a radar map, or the number of points on an ordinal scale used to capture user rating of work environments. Courtrooms across POE studies could be represented by a single number that would stand for the degree of support the courtroom environment provides for the various tasks and functions.

The focus, thus far, has been on representing a courtroom's predicted supportiveness to task performance on a limited number of dimensions, or one number. The KPIs could also be used to predict the user satisfaction in a courtroom, since all the dimensions have a one-to-one correspondence with the variables used in section 9.1.5 (user satisfaction). By plugging the derived value of the KPIs on corresponding variables in the regression equation developed in section 9.1.5, a single number predicted rating between 1 and 7 would be obtained. Such a number would represent the predicted level of satisfaction (workplace satisfaction) in a courtroom.

9.2.5 A worked out example

To illustrate the use of KPIs developed here two federal courtrooms are targeted for comparison. Both the courtrooms are Magistrate Judge courtrooms. One courtroom is in the federal courthouse in Cleveland, OH, and the other courtroom is in the federal courthouse in Hammond, Indiana. Both courthouses are relatively new buildings and opened around the same time. Since they are the same type of courtroom, are of the same

age, and followed the same guideline (U.S. Court Design Guide) for design, the two should be comparable in performance. By assigning the appropriate value for the variables in each equation, values for each indicator were derived. Table 9.53 below lists the values of the KPIs calculated for each courtroom.

Table 9.53: Values of KPIs for the Magistrate Judge courtroom in the federal courthouses in Hammond and Cleveland

| Performance Indicator | Values derived from field measurements | |
|---|--|-----------|
| | Hammond | Cleveland |
| NVT: Near visual task indicator | 6.6 | 6.8 |
| FVT: Far visual task indicator | 4.7 | 4.8 |
| SCI: Speech comprehension indicator | 6.1 | 5.9 |
| SPI: Speech Privacy Indicator | 5.3 | 5.5 |
| CPI: Courtroom physical support indicator | 3.5 | 3.3 |
| PPI: Public physical support indicator | 4.4 | 6.1 |
| WPI: Workstation physical support indicator | 5.3 | 5.4 |
| CSI: Courtroom symbolism indicator | 6.3 | 6.1 |

In this example, user evaluation data on both the courtrooms are available (collected through the POEs). The intention of creating the KPIs is to predict performance based on a representative set of user evaluation data. That could work for existing courtrooms, or for courtrooms in the design phases. The indicator values suggest that both the courtrooms could be predictably rated high on near visual tasks, but lower on far visual tasks. Both courtrooms are comparable in speech comprehension and speech privacy. Similarly, the Hammond courtroom would be rated lower on its attributes related to public waiting area and amenities. Figure 9.3 below provides a visual comparison of the

two courtrooms on a single radar chart. The bold polygon, bounding the two courtroom polygons, represents the maximum value that could be achieved on all of the indicators.

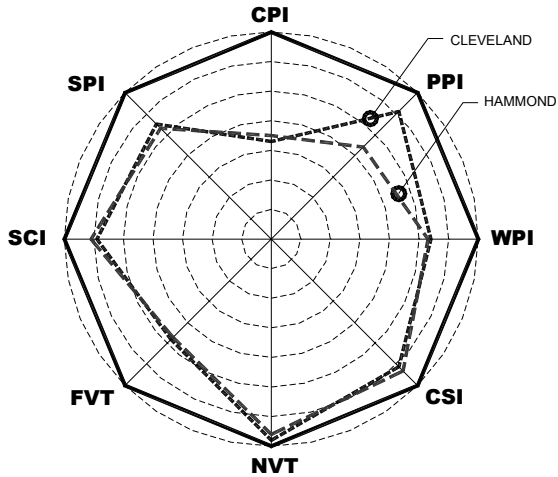


Figure 9.3: KPI radar chart showing the Magistrate Courtrooms in the federal courthouses at Cleveland and Hammond, and predicted value on each courtroom KPI.

As discussed above, the areas of the chart could be compared to assess the relative performance of the courtrooms. Alternately the areas could be normalized to produce single numbers that are bounded between zero and one. The corresponding areas and ratios of the two courtrooms are shown in table 9.54.

Table 9.54: Single number ratings for the Magistrate Courtrooms in the federal courthouses at Cleveland and Hammond.

| Courtroom | Area on radar chart | Ratio of area to maximum obtainable area |
|------------------|----------------------------|---|
| Hammond | 79.29 units | 0.57 |
| Cleveland | 84.52 units | 0.61 |

Both the courtrooms are, at an aggregate level, comparable in the predicted user's evaluation of the supportiveness of the environment to perform their tasks. It is up to the end-user to decide whether 0.61 is acceptable or needs improvement. With similar ratings calculated from a large number of courtrooms, the distance of the ratio of any single courtroom (in standard deviations) from the mean value would provide a clearer idea about the best practices in the field.

Finally, the KPI values calculated above could also be used to predict user satisfaction with their workplace. The regression equation derived in section 9.1.5 provides the basis for prediction. By assigning the values of the KPIs calculated above (table 9.53) for the corresponding variables in the equation on user satisfaction, the Hammond courtroom resulted in a predicted workplace satisfaction rating of 6.2, and the Cleveland courtroom with 6.1. This is in contrast with the ratios obtained above where Hammond is less than Cleveland in predicted supportiveness. The dimensions in the radar chart, however, are un-weighted, where as the regression equation on user satisfaction weighs the KPI values. Note that the variable 'symbol' in section 9.1.5 (which corresponds with the indicator CSI) has the largest standardized coefficient. On that variable, Hammond has a larger value as compared to Cleveland. That partly explains the larger predicted satisfaction level in the Hammond Magistrate courtroom as compared to the Cleveland Magistrate

courtroom. Finally, the KPIs and the single number ratings are time sensitive, since all equations have years of occupation built into the model. That may partly explain the high predicted ratings for the courtrooms in Cleveland and Hammond, since both courthouses are relatively new. With age, the courtrooms would be associated with lower predicted ratings, everything else being equal. The time factor could be used at the design stage too, to predict the length of time for a designed setting before the predicted ratings would be unacceptable.

9.3 Summary

The issues on which users' evaluations were obtained were found to cluster into fewer underlying dimensions. Among visual tasks, tasks on and around ones workstation (such as examining evidence) were found to be different from those conducted across courtrooms (such as observing a witness across the well). Environmental support for auditory tasks clustered into speech comprehension and speech privacy. Support from physical parameters clustered into those related to courtrooms and courtroom wells, public areas outside courtrooms, and workstation and storage dimensions. Multivariate regression of POE data suggested that courtrooms are different from other comparable work settings in some areas. Further, different user groups evaluated the supportiveness of the courtrooms to the tasks performed differently. Finally, the analytical models developed in the regression analysis helped create eight indicators of courtroom performance.

Chapter 10

Summary and Implications

10.1 Summary

The study presented in this dissertation was inspired from repeated concerns in EB literature regarding the limited end-use of POE data in informing the building design phases. The assertion has been that POE data could be used, proactively, in informing decision making in design, facility management and other end uses. Traditional use of POE data and findings, however, has been mostly retrospective. Further, influence of POEs has been generally restricted to facility and portfolio management. It was asserted in this thesis that the problem lies in characteristics of data, and data storage and management practices. Traditional POEs suffered from inappropriate data, incomplete data sets, and inappropriate storage and management practices.

It was argued that a rethinking of the POE data characteristics, and representation of POE data and as-built data in an integrated media would begin to address the above concerns. The development of conceptual modeling techniques such as the EXPRESS data modeling language in ISO-STEP offered a unique approach to integrate as-built and POE data. It addressed several impediments faced in traditional data representations. EXPRESS enables definition of abstract concepts/ constructs and complex relationships between entities that could be included in a holistic representation media. The building

blocks of the modeling language are schemas that allow hierarchical organization of data, as well as nested schemas. Such a structure resembles phenomena and constructs dealt with in POE studies, and offer a richer semantic structure to hold data. Data from multiple studies can be integrated/added without losing the comprehensibility of the model. Further, schemas developed in ISO-STEP are purported to be very complete and comprehensive in representing physical entities of buildings. Exploring the possibility of incorporating evaluation (POE) data and data on users to building schemas constituted the main objective of this thesis.

Emphasis was also placed on data characteristics resulting from POE studies. A traditional POE protocol was revisited from within the framework of performance-based design and evaluation. A protocol was developed for collecting POE data from courtrooms. Thirty-one courtrooms were evaluated as part of the POE process. Courtroom, as a setting, was adopted since the investigator had access to courtrooms and courtroom users. A second rationale behind adopting courtrooms for the study was the lack of knowledge on that setting type in EB. An exploratory study was conducted to identify key tasks users perform in courtrooms. The POEs conducted for the study, was driven by knowledge developed during the exploratory phases. Further, most POE studies, driven by organizational decision-making objectives, measure user satisfaction. It was argued that satisfaction is an abstract construct, which, by itself, may not provide valuable information to designers, and that self-reported task support may be more directly linked to design. In addition, POEs, traditionally, did not collect the corresponding (complete) as-built data on the environments that are rated by users. If

POE data is expected to support design decision-making, a rethinking of the contents of a POE study is warranted. From such a perspective, the study was focused on user's assessment of the level of support their environment provides for the tasks they perform. The questions focus on the tasks users perform in courtrooms, during typical trial proceedings. Measurements of the as-built environment were driven by existing theories or frameworks in the fields of building engineering as well as in EB.

The EXPRESS-G schema developed in this dissertation was translated into a relational database for holding data and running queries. In Chapter 8, a range of query-generated outcomes to support decisions during design and design review was illustrated. Such outcomes include case exploration, precedence analysis, identifying best and worst cases, rating design decisions, and predicting a designed environment's supportiveness to task performance. In addition to query-generated outcomes, multivariate analysis of the data enabled generation of new understanding on courtrooms as work settings. A final outcome relates to the development of courtroom performance indicators. The eight indicators developed in the study are intuitively appealing, and are easy to comprehend. The indicators are developed from representative data sets. Predicted ratings on the indicators are designed to be calculated from data values that are obtainable during the design phases using existing knowledge in engineering. Moreover, the indicators reduce a wide range of design issues to a few dimensions that a designer (or members of a design review team) could easily comprehend and manipulate. This is in contrast to hundreds of pages of printed matters that constituted the typical outcome of traditional POE studies.

A final issue pertains to accessing the data in the database. Unless the data, and the query features, are accessible to remote end-users, the question of POE information support at design and design review phases does not arise. This area of overlap, however, involves work on programming web interfaces, and not directly attempted as a part of the study.

10.2 Areas needing additional work

There are five main areas in this study warranting additional works. The first area relates to the multivariate regression analysis conducted in Chapter 9. Thirty-one courtrooms were visited in the POEs conducted in this study. Out of the thirty-one courtrooms, evaluation data was received from ninety three users in twenty six courtrooms. Three of the ninety-three questionnaires could not be included in the analysis. The resultant sample size is not large enough to feel comfortable with the findings. It is, however, envisaged that in a scenario where POEs are conducted regularly on courtrooms, the database would have sufficient courtrooms to provide robust conclusions. From such a viewpoint, the multivariate regressions conducted on the study provides a good starting point for understanding courtrooms as a type of work setting. It should be noted that many of the study findings confirmed with the assumptions developed during the exploratory study conducted at the beginning of this work. Also, the findings associated with the visual and auditory environments offer meaningful conclusions, and confirm to existing models in building physics. Considering such outcomes, it may not be erroneous to assert that the findings of the analysis are meaningful (and not invalid). From another viewpoint, since the outcomes confirmed with some of the initial assumptions developed

in the exploratory study, it could be asserted that the validity of the questionnaire developed in this study was tested.

A separate issue is that of representativeness. The sample of courtrooms considered in this study is not random. Barring six courtrooms from two federal courthouses, all other courtrooms in the study are located in four judicial districts in the state of Georgia. The findings from data analysis, thus, are not generalizable to all courtrooms in the United States. It is, however, envisaged that with a regular POE program on courtrooms additional data would be uploaded to the database. At a certain point of the POE program, the database would include settings with enough variability to make the findings generalizable. This shortcoming particularly affects the indicators developed in section 9.2. Those indicators are, probably, truer for Georgia courts. It should be noted, however, that the courtrooms in the corpus included wide variability in key physical attributes (area, height, gallery capacity, and similar attributes). The main difference with additional data would pertain to environmental and cultural aspects of courtrooms and courtroom users.

The third area warranting additional works relates to a few of the measurement protocols adopted in this study. As explained in Chapter 6, operationalization of some of the constructs in building physics was found to be difficult in field settings. The most exemplary case is glare, and to a lesser extent brightness. The glare models developed in building physics are so complicated that measuring such concepts in field studies constitutes an extremely difficult task. In this study, the fundamentals behind the glare

models were investigated to come up with a simpler, surrogate, measure. More collaborative studies are required to develop standards for measuring complex environmental parameters. In addition to the translation of engineering models to field protocols, it is also essential to develop ways of measuring environmental attributes while the courtroom is in session. In the current study, variables were measured in vacant courtrooms, since taking measurements when the courtroom is in session posed logistic difficulties. It is conceivable to design measurement protocols that would unobtrusively measure environmental parameters during actual courtroom proceedings. That would improve the validity of POE findings.

Another issue pertains to several potential variables not included in this study, such as air quality and air movement. It is conceivable that certain levels of air quality is not directly perceptible, but bears an indirect influence on work performance. The quality of output from the POEs could be enhanced by introduction of such measures. Further more types of user role could be added with proper logistic planning. Such roles types, including jurors and defendants, could render the study outcomes more effective and holistic.

Courtroom shape is also an attribute warranting attention. In the POE conducted for the study only three predominant types of courtroom shapes were encountered. Courtrooms with other shapes need to be studied to increase the validity of study findings. That will, in turn, necessitate a revisit to the description of courtroom shape. In this study, shape was described as the ratio of the length-to-width of the room. That definition will hold good only when dealing with rectangular or minor trapezoidal shapes. For other shapes a

different type of objective description needs to be developed, that is intuitive and meaningful.

Finally, measurement of performance could be improved. In this study performance was purely based on self-report by respondents. It is conceivable that other types of performance measures be developed and used in POE studies.

10.3 Courtroom design guidelines

A helpful outcome for the designer audience of this dissertation warrants being included before concluding the dissertation. While the primary focus of the study was on modeling POE data using EXPRESS, and demonstrating several scenarios of design information support, the data, nevertheless, provides some courtroom specific suggestions for good performance. In the form of design guidelines, these suggestions define solution spaces that would predictably lead to courtrooms with high supportiveness to the tasks and functions performed during trial. The guidelines, based on the data collected, are described below for separate aspects of the courtroom environment. The guidelines are applicable to Superior Courts courtrooms. Other courtroom types were excluded owing to the lesser number of instances available from the study. The range of values provided against each area suggests the values that would predict favorable rating for environmental support from courtroom users. Some aspects where conclusive evidence is not forthcoming have been excluded from the list.

- Work plane illuminance: illuminance between 30 and 65 FTC would be associated with favorable ratings.
- Task-to-background luminance ratio: a ratio of up to 4:1 predicts best results; up to 8:1 would be associated with favorable ratings.
- Task-to-surrounding luminance ratio: a ratio of up to 5:1 predicts best results; up to 10:1 would be associated with favorable ratings.
- Background-to-surrounding luminance ratio: comparable ratio of luminance predicts best results; up to 4:1 would be associated with favorable ratings.
 - Ratio of wall-to ceiling luminance: a ratio of upto 2:1 would be associated with favorable ratings.
- Horizontal-to-vertical illuminance ratio: a ratio of up to 3:1 in courtroom well as well as gallery would be associated with favorable ratings. Greater contrast would be associated with problems dealing with face observation.
- Window area: courtrooms without windows predicts best results; up to 100 square feet of openings in the walls or roof would be associated with favorable ratings.
- Workstation depth: depth ranging between 2' and 2'6 would be associated with favorable results.
- Courtroom area: an area of up to 1500 square feet predicts best results for trial courtrooms; up to 2500 square feet would be associated with favorable ratings.
- Well length: well length between 20' and 24' would be associated with favorable ratings.
- Reverberation time: reverberation time between 0.7 and 0.9 seconds would be associated with favorable ratings.

- Background noise: NC ratings between 20 and 24 would be associated with favorable ratings.

10.4 Implications and future directions

The direction of inquiry adopted in this study, and study findings, has implications on two areas of academic endeavor. The first implication is for the way POEs (or FPEs) are designed. Most POEs, as pointed out earlier, are designed in such a way that the outcomes are more relevant to decisions in the areas of facility management, portfolio management, and organizational learning. To focus on providing design decision support warrants a rethinking of the POE design. What is needed in that direction is a thorough understanding of the outcomes attempted through a design process. An understanding of end-user needs and the setting type should drive design of questions in a POE surveys. It implies that POE as a branch of scientific inquiry would need to be placed in a classification structure based on study objectives. The questions, tools, and methods adopted for the study would, in turn, depend on the objective of the study. For design decision support, the performance framework provides a good foundation for designing POEs.

The second area of implication relates to development of performance indicators. So far, development of most indicators of building performance has been in the areas of building systems. Predictions on such indicators are done based on theoretical building engineering models. The method developed here provides a way to integrate (or

supplement) engineering models with statistical (probability-based) EB models – the indicators developed in section 9.2 are good examples. Future development of indicators in building design, facility management, facility maintenance and other areas of building procurement and maintenance could initiate a more integrated approach.

Additional studies could be in more than the implication areas mentioned in the previous paragraphs. A major focus of study could be on developing and programming web interfaces that are intuitive to end-users. Such studies could enable better access to data, and more creative querying of the database. A question not addressed in this study relates to data entry and schema modification. Should the data entry be centralized, or should researchers from remote locations be provided access to the database for data entry? In the latter scenario, what would be the most appropriate media to represent the conceptual model to enable the researchers to comprehend the structure of the data? Finally, would the researchers be allowed to change/modify (or add to) the schemas in the model? Future studies could focus on these important questions.

A second area of future inquiry, warranted from the outcomes of this thesis, is to assess the way the outcomes support design decision-making. That includes the contents of the feedback as well as the forms of representation.

A third possible area of future study is in developing more meaningful, and operable, measurement protocols for building physics parameters. That may necessitate collaborative works, and revisiting the fundamentals behind the parameters. Such studies

would greatly enhance the reliability and validity of measurements conducted in field settings.

A fourth direction of inquiry could include modeling textual data collected during POEs, such as user comments, expert observations. The data types used in this study are numeric. Most POEs, however, collect both textual and numeric data. Adding textual data to the model could strengthen the utility of the data outcomes.

Finally, the model could be expanded and tested for other setting types as well as more complex EB constructs. One could pose the question as to whether the data structure developed in this study holds true for all types of courtrooms. Also, questions could address other setting types. Are the issues and classification structure developed in this model also true in (or can be expanded to include) office settings, for instance? Privacy, stress and some other issues seem to be common to offices and courtrooms. Similarly, relationships between elements (distance, elevation, angular dimension) are probably also important in office settings. This is where the model could, possibly, begin to capture knowledge generated through EB research. By expanding from the specific to the general, one could begin to map the commonalities between setting types as well as unique attributes that characterize each setting. It should also be noted that the nested/hierarchical model structure allows each schema of the model to be looked at in isolation and developed further, without affecting other schemas. From such a viewpoint, each schema of the representation poses a research question, parts of which have been investigated in academic research but numerous parts remain to be studied. In its current

form, the model can probably be expanded to offices and schools, although it has not been tested for such expansion capabilities.

A more pertinent question is whether a model can be developed that could be expanded indefinitely as new setting types are added or new sets of issues developed. The answer to that is negative – it would be overtly optimistic to suggest that a generic model with infinite capability for expansion could be developed. The assertion in the previous paragraph that the model could be used to capture descriptive and evaluative data in school and office settings is made owing to the fact that much of the literature on which the POE was developed were based on studies conducted in schools and offices. The investigator gained sufficient knowledge on critical issues and functions in schools and offices to assert the generality of the model to those settings. The problem with expanding the model to all or any other setting type does not pertain to the description of the built/ designed environment. ISO-STEP has made tremendous strides in this direction. The challenge lies in understanding and capturing the range of issues influencing the operation of other settings types. As has been shown in the building model developed in this study, issues are not single-layered representations. Issues have a complex, clustered, and hierarchical representation structure, which could change between setting types (such as gases are important in hospitals, but not in courtrooms). The primary academic challenge, from the viewpoint of expandability of the model, is in understanding and articulating the structure of the range of issues that influence the operation of all settings. That may constitute a potent direction of inquiry for future studies. However, if a specific organization is targeted that deals with a known set of

building types, a generic model could be developed to allow expansibility across those setting types over time. That could constitute a viable and useful alternative direction for future research.

Yet another issue pertains to the addition of guidelines to the model. In its current form the database constitutes a self-help system that leaves the extraction of information and drawing of conclusions to the end user. A related question is of adding design guidelines, inferred from the POE data to the data model. That could provide a quick start point for end users to interact with the database and extract information. Such guidelines will, possibly, reside as attributes of spaces, space zones and elements, rather than as part of the evaluation schema. That is owing to the fact that guidelines are not changed frequently, where as information extracted from the evaluation schema would change continually as more POE data are added to the database. Finally, further studies could focus on the questions posed by the classification structures, introduced through modeling efforts of POE data.

While the primary focus of the study was on the feasibility of EXPRESS modeling technique to represent POE data, and integrate POE data with as-built descriptions of built settings, a unique byproduct of the data analyses in Chapter 9 are the KPIs. The KPIs represent a powerful instrument to represent performance dimensions of built settings, and to structure complex processes of social negotiations. Arguably, more KPIs could be added to the set already described, as more aspects of courtroom performance, such as security, are brought into the purview of the negotiation processes during design

evolution. In essence, developing performance aspects of the social, cultural, and organizational environments in courtrooms (and other important setting types) would constitute one of the most important and useful steps in further research on building performance.

APPENDIX I

LIST OF STUDY VARIABLES

Table I.1: Variable list

| Variable | Description |
|----------------------|---|
| IDENTIFIERS | |
| site | Name of city in which courthouse is located |
| jurisdiction | Administrative jurisdiction (Federal State) of the courthouse |
| cr_id | Name of the courtroom, if any |
| cr_type | Courtroom type (Special Proceedings, District, Magistrate...) |
| AS-BUILT DATA | |
| occupied | Number of years occupied since construction or renovation |
| cr_length | Length of courtroom |
| cr_width | Width of courtroom |
| cr_area | Area of courtroom |
| cr_high | Height of courtroom |
| cr_vol | Courtroom volume |
| cr_capacity | Total capacity in well and gallery area |
| wait_area | Area of any public waiting space assigned to a courtroom |
| wait_capacity | Seating capacity in public waiting area |
| window_a | Total area in windows |
| well_len | Length of courtroom well |
| well_wid | Width of courtroom well |
| well_area | Area of courtroom well |
| well_shape | Shape of courtroom well |
| well_cap | Total seating capacity in courtroom well |
| gall_seat | Total seating capacity in courtroom spectator gallery |
| jury_tier | Number of tiers in jury box |
| work_length | Length of user's workstation |
| work_dep | Depth of user's workstation |
| work_hgt | Height of user's work surface from the immediate floor level |
| bench_ed | Edge lip height of the Judge's Bench from well level |
| bench_fl | Floor elevation of the Judge's Bench from well level |
| sight_ob | Sightline obstruction from user's location |
| work_sto | Total storage capacity in user's workstation |
| judge_lu | Average luminance of the bench-side wall |
| gall_lu | Average luminance of gallery wall |
| jury_luminance | Average luminance of the wall behind jury box |
| fourth_lu | Average luminance of the remaining wall |
| floor_lu | Average luminance of the visible floor |

Table I.1 (continued)

| Variable | Description |
|------------------------|---|
| ceiling lu | Average luminance of the ceiling |
| r time | Reverberation time |
| nc level | NC rating of the courtroom |
| noise m | Noise generated from movement in spectator gallery and entrance |
| temperature | Temperature |
| humidity | Relative humidity in the courtroom |
| work ill | Illuminance on user's workstation |
| vert ill | Vertical illuminance at user's work station |
| task lum | Task luminance at user's location |
| surr lum | Surrounding luminance at user's location |
| back lum | Background luminance at user's location |
| max lum | Luminance of the brightest large source from user's location |
| scrn ill | Screen illuminance on user's workstation |
| scrn lum | Screen luminance at user's location |
| USER DATA | |
| role | User's role (judge, reporter, attorney...) |
| age | User's age |
| gender | User's gender |
| tenure | Number of years served in current position |
| v aid | Type of vision aid used, if any |
| h aid | Type of hearing aid used, if any |
| EVALUATION DATA | |
| well size | Well size |
| well shape | Well shape |
| gall cap | Gallery capacity |
| jury row | Number of tiers in jury box |
| waitsize | Public waiting area size |
| waitcap | Public waiting area seating capacity |
| workarea | Area of work surface |
| wstorage | Workstation storage capacity |
| read doc | Reading printed documents |
| read mon | Reading from computer screens |
| writing | Writing/ typing tasks |
| evidence | Examine evidence |
| facewell | Observe faces in well |
| facegall | Observe faces in gallery |
| loudwell | Loudness of speech in well area |
| clarwell | Clarity of speech in well area |
| loudgall | Loudness of speech in gallery |
| clargall | Clarity of speech in gallery |
| priv oth | Privacy of other's conversation |
| priv sel | Perceived privacy of user's own conversation |
| noise | Noise in gallery and entrance |

Table I.1 (continued)

| Variable | Description |
|-----------|------------------------|
| sightline | Sightline obstructions |
| thermal | Thermal comfort |
| gen env | General environment |
| col ligh | Color of light |
| geometry | Courtroom geometry |
| overall | Overall satisfaction |

APPENDIX II

2.1 Views and discussions on buildings-in-use data

POEs are a rich source of user data in buildings-in-use, and the importance of such data has been underscored by thinkers across several domains. In EB as well as building engineering, discussions have focused on defining more precise user needs, creating more meaningful performance measures, providing information support for design and design review, and many other rationale for the necessity of data on users and their behavior in buildings-in-use. For easier reading, the following sections separate out the EB discussions from those in building engineering, although many arguments seem to be based on a shared logic.

2.1.1 User, user behavior, and feedback in EB Literature

EB, as a field of scientific inquiry, developed during the early 1960s in response to an enhanced awareness about the environment, and a perceived need for decision-making support related to users of built spaces, in the design profession (Saarinen, 1995). A major incentive in creating the field was to enhance the utility of academic research, where the primary focus was on providing design support information to the architectural design and planning professions. The discussions below could be better appreciated when viewed from this perspective.

Part of the reason for an accentuated focus on data from buildings-in-use could be ascribed to concerns regarding the separation between the designers and the users of a building, where designers are increasingly interacting with paying clients. Sommer (1974) describes how the changing economic structure gradually reduced interaction between actual users of a building and the designer. Instead, the architect came to learn about user needs and expectations through corporation boards and public agencies that do not occupy the building in most cases. That was one reason, he asserts, that led designers to search for other means to understand how building users behave in designed spaces. Of course, he was referring to human experts in EB studies to provide information support, but he amply highlighted the need and importance of such information. Underscoring the necessity of cooperation between research and practice Zeisel (1984), too, cites the designer-user gap as the reason warranting such cooperation. He describes how post-industrial society, with mass production culture, resulted in two clients: the client that pays, and the client that uses the building. He further states that understanding the environment-user interactions has been a difficult task, and collaboration with EB research has the potential of bringing knowledge of design impact on users to the designer's attention.

The segregation of designers and users has resulted in an enhanced focus on EB research utilization. The chief concern has been the lack of utilization of research data and findings in design decision-making. Reviewing two decades of POE practice Zimring & Reizenstein (1980) cautioned that presentation of feedbacks from EB studies needs to be

carefully considered in view of the varying characteristics of the end users of such information, in the interest of greater research utilization. Zeisel (1984) articulates this problem through his view on research utilization (Figure II.1), which emphasizes the various different phases of building procurement where EB research findings could potentially be fed. Zeisel also points out that the way research findings could be used in practice is yet to be clarified. As a result, he asserts, most research work in EB remain unused and untested.

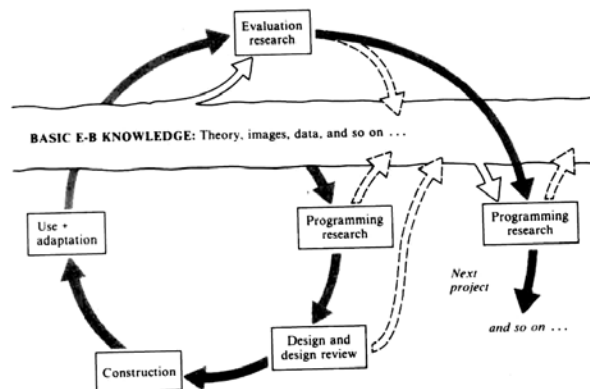


Figure II.1: Zeisel's model showing the different phases where EB knowledge could inform building procurement decisions (source: Zeisel, 1984).

He also underscores the necessity of a better understanding of the ways in which basic research data and findings could be made useful for stakeholders of building projects. While Zeisel, aptly, focuses on rethinking how research data is presented to the end users, Weisman (1998) discusses the failed epistemology of contemporary research paradigms. Weisman, too, believes that the goal of feeding research information to the design and programming process has remained a far-fetched one, and argues in favor of changing the

epistemological underpinnings of EB research in order to achieve an ideal interfacing of research and design practice. Whether the problem lies in collection, storage and representation format, or in epistemological issues, there seem to be an agreement in most quarters that valuable data generated through research is not informing the building design and procurement process.

While many researchers lament on the limited utility of general EB research, some discussions have focused specifically on the inability to make POE findings (a type of EB research) useful. Concerns about limited use have been aired in academic publications as early as in the 1980s. Keys & Wener, (1980) describe how POE documents lie unused even when valuable courses of actions are recommended through such studies. Citing an actual study of a New Mexico public housing project, Kantrowitz & Nordhaus (1980) lament that there was very limited use of the POE report prepared by them. Supporting Zimring & Reizenstein's (1980) contention, they report that the type of presentation prepared by them was not appropriate for the end user. Interestingly, the designers of the project undertook their own POE despite the presence of the POE report prepared by the authors. Further, the authors highlight the problems in translating research information to improved environments. Perhaps, the most elucidating account is provided by Kernohan et al. (1992). They point out the impotence in POE findings, and underscore that current POE practices result in documents that are inaccessible, and stored in formats that are not easily transferable for value addition. They differentiate between retrospective research and proactive ones, and argue that POEs primarily assist in creating guidance documents through retrospective comparison of guidelines with the built environment. They believe

that POEs should be able to provide active guidance to designers, managers and other stakeholders by informing them about users and the way they behave in built environments. In addition, they believe that this issue is not being addressed in academic research or practice. In close agreement to Kernohan et al is Preiser (1996), who believes that the true width and depth of POEs (a misnomer according to him) is not generally realized, and the presence of POE data could help evaluate key concepts and design strategies. Apparently, not much has changed between 1980 and late 1990s. Describing his experience in New Zealand (one of the countries where a healthy support for POE exists), Joiner (1996) describes how research results remained inaccessible to designers. Similar sentiments are echoed in forums in the early 2000s where Vischer (2001), for instance, revisits the perennial problems associated with dissemination and utility of POE findings. She underscores impediments including the nature of questions in user surveys, as well as the complexity involved in design and information management.

A part of the problem associated with limited use of POE data is the absence of a mechanism for feeding (forward) data/information across projects and procurement phases. Many have debated the need for this, arguing from the viewpoint of learning from past experiences. Zeisel (1984), in his hypothesis of how designers work, lays out a description of a prototypical design process model that he believes is followed in most design offices. A portion of his description outlines the importance of building-in-use data in informing subsequent design processes. Referring to process articulations by Hiller, Leaman and Korobkin, he describes that after occupancy, designers may collect post-occupancy data, and such data have utility for subsequent design problems.

Anderson & Weidemann (1997) discuss the value of feedback and feed-forward mechanisms in their decade long research on housing. They point out how such information assist in making focused decisions in the building design and planning process. Based on his decades of experience in conducting POEs, Preiser (2001) believes that the best utility of POE data is in the pre-design phases (feed-forward from other POE studies) of a building procurement cycle. The concept of cross-feeding information between time-lagged procurement cycles is increasingly gaining grounds. Especially in facility management, various mechanisms for doing it has been tried out especially in large organizations (Zimring, 2001, provides an account on Disney). The attempt to feed forward past experiences continues to be an ongoing endeavor.

2.1.2 User, user behavior, and feedback in Building Engineering

Unlike in EB studies, discussions pertaining to buildings-in-use data are relatively more recent in building engineering. Lately, many have highlighted the utility of data from buildings-in-use. Besides the pursuit towards developing more meaningful building performance criteria there are several other rationale behind the current focus on user data. It is noteworthy that, discussions related to data from buildings-in-use are taking place in the context of all phases of a building's life cycle.

The focus on building-in-use data in engineering could be generally attributed to the development of the performance-based practice paradigm, although engineering researchers have advocated similar perspectives decades ago. For instance, according to

Boud (1973), "...a building exists to modify the physical environment to make it more suitable for the activity that is being housed" (p.3), echoing in the process the central essence of the performance movement. More recently, discussing about performance-based procurements in general, Gross (1996) points out the problem of knowledge deficiency. Having incorporated a broader definition of 'performance' which includes economic, social, and other processes in a facility, Gross draws attention to the fact that users requirements (and thus the impact of design/management decisions) are not well understood at present. He also underscores the variations that exist in culture, economic capabilities and expectations, and asserts that such human factors have not been accorded due importance in building engineering research. Elsewhere, in his essay, he cites productivity in workplace, health, and well being of building occupants as important performance aspects, and emphasizes the significance of appropriate information to support decisions affecting those. The need for user data from buildings-in-use is also propounded by Becker (1996). Commenting on future research and development needs of the performance paradigm, she advocates the integration of as-built and POE data, albeit in a narrower domain of building material durability. She propounds the creation of predictive tools based on such integrated knowledge that could support rational decision-making in building design.

Proponents of the performance-based design paradigm are not the only ones to advocate the importance of utilizing data from buildings-in-use. Instances could be found in engineering textbooks where authors have made similar recommendations. Ruck (1989a) explains how subjective field studies evaluating user preferences and lighting efficiency

in workplaces are creating more integrated approaches to engineering design. She believes that such appraisal could lead to better design of the lighting environment. Discussing about daylight values derived from engineering models, Ternoey (2001) recommends to “use the[se] values as a starting point and adjust to professional experience” (p.33), thereby emphasizing the importance of contextual information.

The importance of learning across design phases, and the deficiency of it, is also highlighted by many. Wiezel (1996) argues that appropriate information is not being made available at the design phases. He agrees that through practice-based experience of a designer, some level of incremental learning occurs through informal feed-forward mechanisms (what he terms as “design-principle” based early-phase evaluation by the designer). While this assures the absence of major mistakes in design decisions, Weizel asserts that such assessments lack accuracy, and advocates the need for richer information for greater accuracy in specific design decisions. The absence of good quality feedback is also pointed out by Masat (1996), whose work involved empirical data gathering. Having interacted with groups from a range of disciplines in the construction industry in an attempt to identify key factors leading to building defects, Masat came to the conclusion that in contemporary procurement processes feedback and use of lessons learned constitutes a major weakness in the building industry. He also underscores methodological problems and weaknesses in data capturing and feeding (forward). From a perspective of defect reduction, he highlights the importance of gathering data across projects and phases, and funneling the information to appropriate phases in decision making during building procurement. Presenting their notion of

‘buildability’ as a performance aspect, Chen & McGeorge (1996) offer twelve critical factors (derived from CIIA’s constructability principles) for implementing life-cycle buildability management. One of those twelve factors is the necessity of feedback through post construction analysis of building projects.

Despite the numerous exchange of ideas, there appears to be an absence of a mechanism through which data and information could be meaningfully structured and delivered to end users. In the absence of such a mechanism, some recent EB practices appear to provide alternative means of research-based information support to designers. Such practices highlight the continuing thrust in EB towards a search for a mechanism for knowledge transfer. The next section briefly explores some of the strategies adopted by EB researchers.

2.1.3 Current modalities of informing decision-making processes

In the past decades EB researchers have developed innovative means of addressing the issues of information support through informal feed forward mechanisms. At least four modes of informing building decision-making process has been prevalent (or advocated) in current practice:

- Traditional POE document
- Action research and reflective practice
- Embedded researcher
- Integrated databases

Providing user and usage related information to design teams through printed documents/reports of POE studies remains the most common mode of information delivery. In large organizations like United States Postal Service where prototype facilities are repeated across regions and time, POEs conducted in past projects are offered as sources of knowledge to design team members of new projects (an example is the document produced by USPS, 1996). Other innovative approaches, however, are surfacing in building design practice, which are briefly described below.

Action research and reflective practice in E&B fields have been a major thrust over the past decades towards bridging the knowledge gap between EB research and building design practice. Process Architecture (Horgen et al., 1999), and Placemaking (Schneekloth & Shibley, 1995) are a radical departure from the positivist view of architectural knowledge generation and professional practice. The methods are founded on empowering building users, and enabling their participation in decision-making. Such practices tap into the rich user knowledge base for supporting design decision-making. They put particular emphasis on the value of knowledge held by users through their interaction with the environment. The focus seems to be on bridging the distance between the privileged knowledge held by design professionals and everyday knowledge by users. The EB researcher, as a result, poses as the media through which user data and information from buildings-in-use are channeled to the procurement cycle, bringing more accurate and valid information to the decision-making process.

While Placemaking and Process architecture puts the EB researcher as the primary media for knowledge transfer Preiser (1996)) advocates the idea of embedded researcher. He propounds the inclusion of POE expert-designer in the design team to actively participate in design. The EB researcher thus parallels the role of a consultant engaged in channeling knowledge gained in research to the decision-making table.

Both of the processes above seem to have (at least partially) developed as a response to the necessities discussed in section 2.1.1 and 2.1.2 in this appendix. While bridging the users' and experts' knowledge is offered as explicit goals, the researchers, nevertheless, behave as the medium for knowledge transfer. These approaches, however, adopt organizational learning methods, which are not the typical method used in traditional POE practice. The goal is to articulate the intricacies of a particular context, as opposed to developing common knowledge that could be generalizable (see chapter 2). Also the knowledge base that provides information support is specific to the researcher, and lacks a universally accessible data repository.

For broader accessibility of data on users, Masat (1996) views the necessity of creating a knowledge management database that could store lessons learned and other information, and support a feedback mechanism. He feels the urgent necessity of organizing data across projects (although his discussions pertained mainly to data on building materials). In a more holistic approach, Zeisel (1984) addresses the issue of appropriate representation of information to the designer. He believes that impact of certain design decisions on users could be made predictable if the research data could be organized into

a meaningful, cohesive structure. Further, he highlights the importance of such information in projects where the actual user of the building is unknown, thus eliminating any planned interaction and testing. In such cases, he asserts, data gathered from other projects involving representative substitute user population (similar population, problem, and setting) could provide valuable information to the designer, in terms of user behavior in the environment, and, thus, in evaluating design decisions. Probe (Cohen & Gilbert, 1999) is a recent instance of use of integrated database in practice, in the area of post occupancy evaluation. Involving several office buildings in the United Kingdom, the evaluation procedure includes collection of data on user satisfaction. This process helps in rating buildings on several performance scales. The approach, however, appears supportive to portfolio management strategies, and offers little utility in building design and design review. Building data repository for design information support, however, involves issues related to characteristics of data and data structure, which bear considerable leverage on the comprehensibility and use of feedback. Such issues are covered in chapter 2.

2.2 POE

Post-occupancy Evaluation (POE) originated during the 1960s as a one-time evaluation of public housing, when things in public housing design were apparently going wrong. Since then POE has evolved and expanded in scope as well as philosophy, with each POE expert attempting his/her own definition of the process, although there are some common subsets to the definitions. A basic, simple definition is provided by Preiser, Rabinowitz,

& White (1988). According to the authors “post-occupancy evaluation is the process of evaluating buildings in a systematic and rigorous manner after they have been built and occupied for some time” (p.3). Preiser (1994) associates the term ‘occupancy’ with ‘occupancy permit’ that is issued to the clients after a building is deemed safe for occupation by the local governments. This component of POE has remained as an important data set since the very beginning. The differences lie in the way researchers have expanded its scope from this basic definition.

Zimring & Reizenstein (1980), providing an overview of POEs (which were presumably still at a stage of infancy at the time of writing of the article) offered a working definition of POE as “the examination of the effectiveness for human users of occupied designed environments. Effectiveness includes the many ways that physical and organizational factors enhance achievement of personal and institutional goals” (p. 429). The authors further elaborated the fundamental differences between POE and conventional EB research (this characterized the early development of POE studies, and provides a good way to contrast early POEs with some of the contemporary ones). POE studies deal with a single setting (in terms of building type), where as general research in psychology and sociology are interested in psychological and sociological phenomena across building types. Second, POE studies differ vastly from the experimental studies that are popular in psychological research. Experimental research essentially involves the designed manipulation of variables. POE have no way to manipulate variables, and hence essentially descriptive in nature (according to the authors). Further, it is also difficult to control variables in field settings where POEs are conducted, which leaves quasi or non-

experimental designs as the only tools in the hands of POE researchers interested in contributing to theoretical knowledge. Finally, since POEs are application oriented, they are different from conventional EB or social science research. The fundamental orientation on practical application in POE studies is also reflected in the definition provided by Keys & Wener (1980), who view POE as “a data-based method of environmental intervention, characterized by a deliberate effort by a change agent to use data as a means of initiating change in an organization” (p.533).

While initial POEs focused on providing information to clients and building managers on things that need to be corrected in order for the building to be used as intended, POEs gradually grew in scope as is evident in White's (1991) definition, which states that “fundamentally, POE involves the evaluation of the performance of buildings, the use of the lessons learned from the study in future projects and the use of the findings to improve the evaluated building and other built facilities (repairs, renovations, etc.)... POE is one aspect of the larger field of building diagnostics. Whereas POE deals with the assessment of the way a building has performed up to the present time, building diagnostics include the prediction of likely building performance in the future” (p.1). This suggests the beginning of a desire to feed lessons (knowledge) from POEs to future projects, and a need for predictability of outcomes from design decisions.

The definition of POE witnessed further changes as the profession began to explore new territories. By mid-1990s Preiser (1996) was defining the term ‘post-occupancy evaluation’ as a misnomer. The information generated from POE studies was apparently

suitable for wider applications, with Preiser suggesting applications in all phases of a building's delivery cycle as well as the building's entire life cycle. Besides being seen as a process to rectify a product (in this case a building), the scope was being expanded to include processes leading to the product. Preiser discusses about the pre-design and design cycles (and the way a POE expert can contribute to evaluation of design concepts), thus clearly aligning with White's (1991) attempt at feeding lessons (knowledge) learned from POEs to the design decision-making process. Predictability of performance is also addressed by Preiser (2001) as an integral part of the POE (misnomer) process.

Reflecting this trend Vischer (2001) provides a modified definition that states that “loosely defined, POE has come to mean any and all activities that originate out of an interest in learning how a building performs once it is built, including if and how well it has met expectations and how satisfied building users are with the environment that has been created”. The basic definition remains (in terms of the data set), which involves the study of a building after it has been occupied. Preiser (2001), however, attempted to expand the data set by including data from the building programming, design and delivery cycle. The changes to the definition and scope of POE can be partly attributed to the accountability that POE studies offered to assess performance of building managers, for which there were no tools available in the past. Watson (2003) reflects this by defining POE as “a tool to account for building quality – essential when organizations are required to demonstrate that building programs are being responsibly managed”. The

changes to the definition of POE, over the past decades, also reflect the changes in practice.

2.2.1 POE Practice

The development of the POE practice can be best presented in a chronological manner. As pointed out earlier, POEs started with one-off studies during the late 1960s (Preiser, 2001). Initial efforts were focused on solving problems related to housing needs of disadvantaged people and improving the quality of public housing (Vischer, 2001). Preiser (1994) suggests that the early focus on residential architecture (specifically, dormitory population) was owing to the ready availability and willingness of such a user group.

The 1970s witnessed major expansions in POE studies. Courthouses, prisons and hospitals were targeted for evaluation (Vischer, 2001). Preiser et al. (1988) report that this period witnessed the first major collaboration between architectural and medical professionals in hospital design. During the same period offices and schools were beginning to be targeted by POE researchers in the Great Britain. The period, on the whole, witnessed an adaptation of research methods and tools from diverse fields in POE studies, including survey, interview, observation techniques, cost-based building evaluation model, triangulation methods, systematic observation, behavioral mapping, archival data, and photographic records. POEs, with the new tools, embraced a wide variety of building and occupant types for systematic study. The large body of

knowledge, generated in the process, led to the development of a number of design guides and standards (Preiser, 1994). Some researchers began to expand POEs from one-time, single unit evaluation to system-wide evaluations (Preiser, 2001).

The progress during the 1970s helped POE develop into a discipline on its own right during the 1980s, with a established network of researchers, a developing corpus of knowledge, and a bag of accepted research tools and methods (Preiser et al., 1988). The 1980s also attracted the attention of the private sector, and occupant satisfaction surveys were conducted in numerous offices, schools and hospitals. It was during this period that some researchers began to design studies that had both objective environmental data as well as subjective ratings, with the goal to investigate correlation between the two (Preiser, 1994). Further, the hangover from the energy crisis of the 1970s, and subsequent thrust in building component manufacturers in developing energy efficient systems, led to the expansion of POEs into domains of energy use and occupant comfort (Vischer, 2001), which probably explains the then developing interest of the private sector in POE studies.

The developing corpus of knowledge, methods, and expertise resulted in some other outcomes too. During the 1990's POE tools and data was considered appropriate to develop accountability measures. Joiner (1996) discusses the growth of POE in New Zealand, where government architects, until then, used accounting and engineering measures (principally time and cost) to demonstrate performance in designed settings. POEs introduced new measures of performance by demanding ways of demonstrating that the designed settings work well for the users and building managers. Since then, POE

has emerged in New Zealand as a process offering social negotiation between stakeholders of a building project. Other contemporary developments in POE includes the process-oriented approach propounded by Preiser (1996), that also examines influential economic, political, social and regulatory factors that impact the outcome of a building procurement cycle. Preiser (2001) attempted to rename POE as BPE (Building Performance Evaluation), and UDE (Universal Design Evaluation). His attempts has been towards effectuating a more holistic approach to building evaluation that also takes into account important factors influencing the process leading to the building product. Within the ambits of UDE Preiser classifies the building cycle into six major phases: planning, programming, design, construction, occupancy, and recycling.

Along with the evolving practice of POE, the declared purpose of POEs has changed too. While initial POEs had a limited purpose focused on a single building (which has remained a vital objective areas) newer requirements for POEs have surfaced. More recently, the possibility of systematic organizational learning through POEs have been explored (Zimring, 2001), and in the future such a purpose could also be assigned to POE studies (or any other appropriate name that might be assigned to this class of research; FPE, acronym for Facility Performance Evaluation, is already in vogue in large organizational owners of real estate). The development of POE practices, the changing definitions, and the broadening areas of purpose, underscores the rising importance of information management. From single building, one-time use, POEs are being attempted to serve much broader function in terms of research knowledge generation, and propagation of such knowledge across buildings, organizations, and time-lines.

2.2.2 POE Types

The wide range of objectives being attempted through POEs, the numerous stakeholders being addressed, and the plethora of methods being adopted to POE studies have resulted in a wide variety of POE practices. New methods are being tested as frequently as POE studies are being conducted, although acceptance of such methods may take time. These factors make it difficult to come up with some clear-cut classification structure. A way of classification could be attempted based on the time when the study is conducted and the type of output of such studies. While some of the researchers mentioned above have tried to expand POE to include programming and design phases of building procurement, suggestions like Universal Design Evaluation and Process-Oriented Approach are in a stage of infancy, considering the fact that a systematic method for capturing data from phases other than after occupancy of a facility has not yet fully materialized. A methodology for capturing data on socio-political-economic forces that impact design decisions is probably at a developmental stage. When evaluation of design decisions is discussed in the context of forward-feeding knowledge to future design cycle, the current practice has more been in terms of individual researcher applying knowledge developed through their own experience in influencing design decisions. In a context where the field is yet to arrive at more formal methods of knowledge transfer, the classification structure described below may serve appropriate for the time being.

One type of POE constitutes a quick walkthrough in the early (or immediate pre-occupancy) phases of a building's life span. Those typically involve short periods of study, using small teams of stakeholders, and result in report-based recommendations for the improvement of a facility. Methods are mostly qualitative, and make use of organizational learning tools. The recommendations may be for immediate, short or long-term measures, but are generally focused on improving a single facility. Group discussions, touring interviews, photography and expert observations are some of the frequently used research methods. Watson (1998, 2003) provides some instances of the use of such methods in New Zealand.

More prevalent are POEs that are conducted about six to nine months after occupancy of a building. Traditionally, these studies have focused on finding mismatches between needs and provisions, as well as in identifying areas for correctional measures in new facilities. Questionnaires distributed to occupants have been a common way of collecting data for these studies, which result in descriptive, objective (sometimes subjective) outcomes. Modern technology has enabled such studies to use web-based surveys for collecting data from building occupants. However, observation and expert evaluation also have been used in such studies (or a combination of the methods), the USPS study being an example (see Kantrowitz & Farbstein, 1996, for details). Reports of these types of study as well as the walkthrough interviews have been typically in form of bound documents that are submitted to the sponsors of the evaluation study.

Several large organizations, both in the public and the private sectors, have been using regular POE studies to inform organizational decision-making. Zimring (2001) provides some good instances of these (also see Heerwagen, 2001, for some pertinent discussions). Such studies are conducted on a regular basis, use multiple methods, and study outcomes can be found in many forms, although results reach only selected people in the organization. Those studies are used in informing decisions regarding portfolio (building asset) management, identifying business drivers, and isolating critical lessons learned data. Results of such studies, however, are not in the public domain, and are not available to the programming and design phases of new developments.

APPENDIX III

POE SURVEY QUESTIONNAIRE

Courtroom Users Questionnaire

Courtrooms Performance Evaluation

Georgia Institute of Technology
College of Architecture

Date of survey:

Courthouse Name:

Courtroom ID:

Courtroom Type:

For use by Investigator

Greetings!

This study aims to assess the degree to which your courtroom setting supports the various tasks and operations conducted by you, particularly the layout and amenities, lighting, and the acoustical design. Your feedback would enable us to assess courtroom designs.

All questions below are targeted towards 'YOU' performing your job in a 'SPECIFIC' courtroom (named above). Please report what you feel is the appropriate response for each question. It is possible that you are also concerned about other aspects of this courtroom or the courthouse that are not addressed in this questionnaire. Please note any such concern on the back of this form, and try your best to ensure that your response to the questions in this questionnaire reflect the aspects of the courtroom that are listed, not your other concerns; your objective and honest response will improve the accuracy of assessment.

Your responses will remain private and confidential. Findings will be reported in aggregated form and will have no identifiable links to you. Your participation in this study is voluntary; you may decline to participate. You are free to refuse to answer any or all questions in this questionnaire. If you decide to participate, you may withdraw at any time. If you withdraw before data collection is completed your data will be returned to you or destroyed.

For all questions below, please check only one box that matches your response.

For questions not relevant to your work—that is, any questions not related to the task you perform—or to amenities not provided, please check the 'N/A' box.

Courtrooms Performance Evaluation

1) **Layout Performance:** this section includes questions regarding the size, shape, and capacity of courtroom spaces, and similar issues, and whether they are adequate for efficient conduct of courtroom proceedings.

| | very inadequate | inadequate | somewhat inadequate | neutral | somewhat adequate | adequate | very adequate | N/A |
|---|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 1. <i>Well size (jury selection; multi-defendant trial; presenting to jury.): WELL SIZE, for efficient conduct of courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2. <i>Well Shape (jury selection; multi-defendant trial; presenting to jury.): WELL SHAPE for efficient conduct of courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3. <i>Gallery capacity (jury selection; attorney/witness waiting.): GALLERY SEATING CAPACITY for efficient conduct of courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 4. <i>Jury box tiers (hearing, multi-defendant trial.): NUMBER OF TIERS IN JURY BOX, for efficient conduct of courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 5. <i>Size of public waiting (jury selection; attorney/witness waiting.): SIZE OF PUBLIC WAITING AREA, to reduce disturbance during courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. <i>Seating capacity in public waiting (jury selection; attorney/witness/defendant waiting): SEATING CAPACITY IN PUBLIC WAITING AREA, for efficient conduct of courtroom proceedings, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Courtrooms Performance Evaluation

| | very inadequate | inadequate | somewhat inadequate | neutral | somewhat adequate | adequate | very adequate | N/A |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 7. <i>Available work surface (during pretrial hearing, jury selection, hearing, multi-defendant trial, sentencing...): WORK SURFACE to conduct your regular tasks, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 8. <i>Storage space: BUILT-IN STORAGE SPACE provided in your work station, to conduct your regular tasks, is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 2) Visual Tasks: How adequate are the conditions in your courtroom for the following tasks involving: | | | | | | | | |
| 9. <i>Reading from printed documents – including legal documents:</i> Conditions for performing READING TASKS in your courtroom are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 10. <i>Reading from computer monitors:</i> Conditions for READING/SEEING FROM COMPUTER MONITORS in your courtroom are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 11. <i>Taking notes, filling forms, cataloging evidence, using computer keyboard:</i> Visual conditions for WRITING/TYPING TASKS in your courtroom are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 12. <i>Examining evidence:</i> Conditions in your courtroom for VISUAL INSPECTION OF EVIDENCE are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Courtrooms Performance Evaluation

| | very inadequate | inadequate | somewhat inadequate | neutral | somewhat adequate | adequate | very adequate | N/A |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| 13. <i>Faces in Well - judge, deputy, reporter, jury, attorney, witness:</i> Conditions to clearly SEE FACES/FACIAL EXPRESSIONS in the Well area are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 14. <i>Faces in Gallery - potential jurors, attorneys, witnesses, defendants:</i> Conditions to clearly SEE FACES/FACIAL EXPRESSIONS of people in gallery are: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 3) Auditory Tasks: The following questions are about speech and hearing tasks. | | | | | | | | |
| 15. <i>Speech of people within the Well area: examining deposition evidence; listening to video presentation:</i> From your position(s) of work in the courtroom, the LOUDNESS OF SPEECH from the Well is: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 16. <i>Understanding speech in Well; deposition evidence; video presentation:</i> From your position(s) of work in the courtroom, the CLARITY OF SPEECH from the Well is: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 17. <i>When people in the Gallery speak; e.g. jury selection:</i> From your position(s) of work in the courtroom, the LOUDNESS OF SPEECH from the Gallery is: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 18. <i>Ability to clearly understand speech from the Gallery; e.g. jury selection:</i> From your position(s) of work in the courtroom, the CLARITY OF SPEECH from the Gallery is: | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |

Courtrooms Performance Evaluation

| | | | | | | | | |
|---|--|---|--|-------------------------------------|--|---|--|---------------------------------|
| 19. <i>Overhearing other's private discussion/conference: From your position(s) in the courtroom, the PRIVACY OF OTHER'S CONVERSATION is:</i> | very inadequate <input type="checkbox"/> | inadequate <input type="checkbox"/> | somewhat inadequate <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat adequate <input type="checkbox"/> | adequate <input type="checkbox"/> | very adequate <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 20. <i>Your assessment that others cannot hear you when you are discussing/conferring: From your position(s) in the courtroom, the PRIVACY OF YOUR CONVERSATION is:</i> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 21. <i>MOVEMENT OF PEOPLE in Gallery in/ out of the court when courtroom is in session is:</i> | very quiet <input type="checkbox"/> | quiet <input type="checkbox"/> | somewhat quiet <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat noisy <input type="checkbox"/> | noisy <input type="checkbox"/> | very noisy <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 4) Other topics: The following questions inquire about other topics that are believed to influence courtroom performance. | | | | | | | | |
| 22. <i>SIGHTLINE OBSTRUCTIONS arising from courtroom elements (furniture, equipment) and people are:</i> | very infrequent <input type="checkbox"/> | infrequent <input type="checkbox"/> | somewhat infrequent <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat frequent <input type="checkbox"/> | frequent <input type="checkbox"/> | very frequent <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 23. <i>The THERMAL CONDITIONS in your courtroom are:</i> | very uncomfortable <input type="checkbox"/> | uncomfortable <input type="checkbox"/> | somewhat uncomfortable <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat comfortable <input type="checkbox"/> | comfortable <input type="checkbox"/> | very comfortable <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 24. <i>In general the ENVIRONMENT IN YOUR COURTROOM during typical courtroom sessions leaves you:</i> | very distracted <input type="checkbox"/> | distracted <input type="checkbox"/> | somewhat distracted <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat attentive <input type="checkbox"/> | attentive <input type="checkbox"/> | very attentive <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 25. <i>COLOR OF LIGHT in your courtroom, to symbolize the dignity of law and importance of the justice system, is:</i> | very inadequate <input type="checkbox"/> | inadequate <input type="checkbox"/> | somewhat inadequate <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat adequate <input type="checkbox"/> | adequate <input type="checkbox"/> | very adequate <input type="checkbox"/> | N/A <input type="checkbox"/> |

| | | | | | | | | |
|--|---|--|---|-------------------------------------|---|--|---|---------------------------------|
| 26. PHYSICAL FEATURES of your courtroom, to symbolize the dignity of law and importance of the justice system, are: | very inadequate <input type="checkbox"/> | inadequate <input type="checkbox"/> | somewhat inadequate <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat adequate <input type="checkbox"/> | adequate <input type="checkbox"/> | very adequate <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 27. On the whole, considering all aspects of your courtroom (including those not included in this questionnaire) you would rate your courtroom as: | very unsatisfactory <input type="checkbox"/> | unsatisfactory <input type="checkbox"/> | somewhat unsatisfactory <input type="checkbox"/> | neutral <input type="checkbox"/> | somewhat satisfactory <input type="checkbox"/> | satisfactory <input type="checkbox"/> | very satisfactory <input type="checkbox"/> | N/A <input type="checkbox"/> |
| 5) Finally, the personal information below would help us make our findings more meaningful. | | | | | | | | |
| 28. Your Position: | <input type="checkbox"/> Judge | <input type="checkbox"/> Deputy | <input type="checkbox"/> Reporter | <input type="checkbox"/> Attorney | <input type="checkbox"/> Security | | | |
| 29. Age as of last birthday: | _____ years old | | | | | | | |
| 30. Gender: | <input type="checkbox"/> Female | <input type="checkbox"/> Male | | | | | | |
| 31. Number of years in current position as of today: | _____ years _____ months | | | | | | | |
| 32. Do you use vision aid while performing your duty: | <input type="checkbox"/> Yes | <input type="checkbox"/> No | If Yes, what kind _____ | | | | | |
| 33. Do you use hearing aid while performing your duty: | <input type="checkbox"/> Yes | <input type="checkbox"/> No | If Yes, what kind _____ | | | | | |
| 6) Please note here any other issue that you consider important for the performance of your courtroom, not covered in the questions. | | | | | | | | |

I greatly appreciate the time, energy and effort that you have devoted to completing this questionnaire. Thank you very much.

3.2 Data Collection Protocol

| SITE VISIT PROTOCOL | | |
|---------------------|------------------------------|---|
| | | |
| SITE | Courthouse Type | |
| | Building name | |
| | Jurisdiction | |
| | City Name/ State Name | |
| | Courtroom Type | |
| | | |
| | | |
| LAYOUT | | |
| Courtroom | Courtroom Length | |
| | Courtroom Width | |
| | Ceiling Height | |
| | | If irregular shape draw all dimensions: |
| | | |
| Public Waiting Area | Public waiting area length | |
| | Public waiting area width | |
| | | If irregular shape draw all dimensions: |
| | Public waiting area capacity | |
| | | |
| Well area | Well length | |
| | Well width | |
| | | If irregular shape draw all dimensions: |
| | Total Well capacity | |
| | | |
| Gallery | Gallery seating capacity | |
| | | |
| Windows | Window area | Judge wall |
| | | Gallery wall |
| | | Jury wall |
| | | fourth wall |
| | | |
| Bench | Floor elevation | |
| | Edge lipping height | |
| | Work surface length | |
| | Work surface depth | |
| | Work surface height | |
| | workstation storage | Drawers |
| | | Shelves |
| | | |
| Deputy | Work surface length | |
| | Work surface depth | |
| | Work surface height | |
| | workstation storage | Drawers |
| | | Shelves |
| | | |
| | | |
| | | |
| | | |

| | | | |
|------------------|---------------------|---------|--|
| LAYOUT | | | |
| Reporter | Work surface length | | |
| | Work surface depth | | |
| | Work surface height | | |
| | workstation storage | Drawers | |
| | | Shelves | |
| Attorney | Work surface length | | |
| | Work surface depth | | |
| | Work surface height | | |
| | workstation storage | Drawers | |
| | | Shelves | |
| Security | Work surface length | | |
| | Work surface depth | | |
| | Work surface height | | |
| | workstation storage | Drawers | |
| | | Shelves | |
| Witness | Floor elevation | | |
| Jury | 1st row elevation | | |
| | # of tiers | | |
| | | | |
| | | | |
| ACOUSTICS | | | |
| | Reverberation Time | 63 | |
| | | 125 | |
| | | 250 | |
| | | 500 | |
| | | 1000 | |
| | | 2000 | |
| | | 4000 | |
| | | 8000 | |
| | Background Noise | | |
| | | 63 | |
| | | 125 | |
| | | 250 | |
| | | 500 | |
| | | 1000 | |
| | | 2000 | |
| | | 4000 | |
| | | 8000 | |
| | Impact Noise Door | 250 | |
| | | 500 | |
| | | 1000 | |
| | Impact Noise Seats | 250 | |
| | | 500 | |
| | | 1000 | |
| | | | |
| | | | |

| | | | |
|---------------------|--------------------------|--|--|
| LUMINANCE | Judge wall | | |
| | Gallery wall | | |
| | Jury wall | | |
| | Fourth wall | | |
| | Floor | | |
| | Ceiling | | |
| Bench | Task | | |
| | Background | | |
| | Surrounding | | |
| | Largest/Brightest Source | | |
| Deputy | Task | | |
| | Background | | |
| | Surrounding | | |
| | Largest/Brightest Source | | |
| Reporter | Task | | |
| | Background | | |
| | Surrounding | | |
| | Largest/Brightest Source | | |
| Attorney | Task | | |
| | Background | | |
| | Surrounding | | |
| | Largest/Brightest Source | | |
| Security | Task | | |
| | Background | | |
| | Surrounding | | |
| | Largest/Brightest Source | | |
| Window Luminance | Judge wall | | |
| | Gallery wall | | |
| | Jury Wall | | |
| | Fourth Wall | | |
| CHROMATICITY | Bench | | |
| | Deputy | | |
| | Reporter | | |
| | Attorney | | |
| | Witness | | |
| | Security | | |
| | Gallery | | |
| | | | |

| | | | |
|--------------------------|-------------------|--|--|
| ILLUMINANCE | Judge task | | |
| | Judge Screen | | |
| | Judge Vertical | | |
| | | | |
| | Deputy task | | |
| | Deputy Screen | | |
| | Deputy Vertical | | |
| | | | |
| | Reporter task | | |
| | Reporter Screen | | |
| | Reporter Vertical | | |
| | | | |
| | Witness Task | | |
| | Witness screen | | |
| | Witness Vertical | | |
| | | | |
| | Jury task | | |
| | Jury screen | | |
| | Jury vertical | | |
| | | | |
| | Attorney task | | |
| | Attorney screen | | |
| | Attorney vertical | | |
| | | | |
| | Security task | | |
| | Security screen | | |
| | Security vertical | | |
| | | | |
| | Gallery task | | |
| | Gallery screen | | |
| | Gallery vertical | | |
| | | | |
| | | | |
| | | | |
| TEMPERATURE | Well | | |
| | Gallery | | |
| | | | |
| HUMIDITY | Well | | |
| | Gallery | | |
| | | | |
| | | | |
| SIGHTLINE PROBLEM | Bench | | |
| | Deputy | | |
| | Reporter | | |
| | Attorney | | |
| | Security | | |
| | | | |
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| PHOTOS | | | |
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Appendix IV

4.1 Variables influencing visual task performance

4.1.1 Illuminance

Illuminance is a measurement of the amount of luminous flux incident on a surface per unit area. Luminous flux is the range of radiant energy radiated from a light source that stimulates the visual perception. Illuminance is one of the first variables to be targeted in engineering research, particularly for industrial and military applications where task complexity is high and lighting levels provided were low compared to today's standards. In fact, researchers measured visual acuity, where visual acuity is defined as sharpness of vision – something experienced by everyone when they move to better-lighted area when examining or dealing with small details (Boud, 1973). Most textbooks and review literature on lighting agree that acuity increases rapidly with increase in illuminance up to a level, beyond which increment in illumination result in little improvement in visual acuity (Boud, 1973). The background illumination also matters. Laboratory experiments suggest that visual acuity increases with increase in background illumination, but the relationship is moderated by the color of the object under study vis-à-vis the background (light object against dark background and the reverse; Boff & Lincoln, 1988a). While it could be reasonably assumed that visual acuity is related to task performance, some researchers report studies focused on task performance. Ruck (1989b) cites the reported

work of Neston back in 1945. Neston conducted field studies as well as laboratory experiments to investigate the influence of illuminance on task performance. He reports that (as in visual acuity) increasing the illuminance follows the law of diminishing returns. As illuminance is increased, performance improves until a saturation point is reached, beyond which illuminance has little impact on performance. There is also an interaction effect between illuminance and the size and contrast of the details (Katzev, 1992; Ruck, 1989b). As the size and contrast is reduced, the illuminance level needs to be higher at which it saturates. This phenomenon is reflected in the lighting codes where recommended illumination levels vary depending on the complexity of task involved (Rea, 2000). While low levels of illumination is mostly reported to affect acuity or performance, Ruck also suggests (as pointed out earlier) that too much light (illuminance) could cause eye-strain thus affecting performance, suggesting that an optimal range of illuminance exists for different task types. Changes in work environment have added some complexity to the issue of illuminance level. As Ruck (1989a) points out, generally, high illuminance level is recommended for office work to create good visibility conditions. However, many office tasks currently also include work on monitor screens. Ruck, citing the previous research works, believes that for such tasks low level of illuminance is recommended to ensure greater visibility. However, as technology changes, allowing users to change the color, brightness and contrast of monitors, newer studies/recommendations are warranted. Ruck's suggestion here should be seen in light of the period in which Ruck's book was published, and that there has already been 15 to 30 years of technological improvements since the dates of works cited by Ruck.

Many of the studies, however, deal with contrived tasks that could have lesser relevance with kinds of work people actually do in courtrooms. Several studies have tried to create more realistic tasks for studying the relationship between lighting and performance. Some researchers have gone a step further in suggesting that the association between lighting and performance is mediated by affect, where they argue that the quality of lighting bears impact on the subject's mood, which, in turn, affect performance. Several others cite the theory of arousal, suggesting that higher lighting levels lead to greater arousal, arguing that moderate levels of arousal lead to improved performance. Such studies can be found more in the topic of light color as compared to illuminance. Many studies deal with both illuminance and spectral power distribution, and some of those are reported here.

Baron et al. (1992) designed an experiment with the objective to investigate the impact of illuminance and spectral distribution on performance on a wide range of work-related tasks. Part of their hypothesis involved the mediating role of positive affect. They performed the experiment in a specially prepared room with off-white walls and ceiling, where the tasks included, among others, reading the personal folder of an imaginary employee, evaluation of the employee and word categorization. 64 male and 27 female undergraduates from an introductory psychology class participated in the study. Two illumination levels (150 FTC and 15 FTC) and four different fluorescent lamp types – warm white (3000k), cool white (4200k), natural white (3600k), and Design 50 (5000k)- was used to create variations in lighting conditions. Results suggested no gender difference on any of the dependent measure. However, illuminance had a significant impact on subject's performance on several tasks. Subjects in lower illuminance levels

assigned higher rating to an imaginary employee and included more non-typical exemplars in word categorization as compared to subjects in high illuminance level. This result may partly support contentions above (Ruck, 1989b) regarding the negative impacts of high illuminance. Lamp color produced less consistent results (which is in line with many other studies that will be discussed in the section on spectral composition). The performance appraisal task demonstrated a significant interaction between illuminance and color, where cool white lamps worked against the positive effects of lower illumination level. No mediating role of affect was found. Another study (Katzev, 1992) investigated the impact of illuminance and light color (of energy efficient office lighting systems) on productivity, preferences, and affect. Katzev created four identical test mock-up office spaces with neutral gray color scheme for walls and floor carpets. The lighting in the mock-ups was varied through illuminance (35 and 100 FTC), and lamp type (F32T8 and F40DBXT4). 18 male and 18 female office personnel worked for a full working day in the experimental set-up. Tasks included error detection, spreadsheet entry, reading comprehension, and typing (these tasks, of all studies reported here, are closest to the type of tasks performed in a courtroom). Measurements also included a mood test. Results suggest that lamp type had only a relatively modest impact on reading performance, no impact on cognitive tasks, and little impact on mood. In illuminance, however, subjects showed a preference for lighting levels of 45 to 55 FTC. Also, a larger preference was for indirect lighting system, with subjects showing their disapproval for direct down lights. These two studies suggest an inverted 'U' shaped association between illumination and subjects performance and preference. However, a meta-analysis of lighting studies (Gifford et al., 1997) suggests a different type of association, where

the slope increases as levels of illumination increases (authors did not suggest a reversal of slope at higher illumination levels). The authors started off with the hypothesis that greater illuminance increases productivity. They conducted an on-line computer search, reference tracking, previous reviews, and written requests to researchers in the field to obtain relevant literature. 11 articles satisfied the pre-determined criteria for inclusion in the analysis. The studies were dated between 1938 and 1990. Result of the meta-analysis suggests a positive association between illumination and performance (reading speed, amount written, etc...) of office tasks. The authors suggest a linear relationship between the variables. Thus an increase of illuminance from 7 FTC to 45 FTC predicts a productivity increase of about 14% (the direction of the association is in agreement with the studies mentioned above). However, further increase, from 45 FTC to 200 FTC predicts a further increase of 19% in productivity.

Some studies on illuminance, however, have reported zero association between illuminance and performance. Charness & Dijkstra (1999) designed a study to investigate association between ambient lighting level and legibility performance, and to see if the relationship is moderated by age. They conducted a field study and measured illuminance levels and legibility performance of 102 non-government business employees during a typical day. In each of the 51 business establishments surveyed, they studied one staff under 40 years of age and one over. Tasks included newspaper tasks, proof reading tasks, and phone book tasks. The businesses surveyed varied from auto shops to more traditional closed offices. A confounding result was the lack of any significant result of ambient illuminance. The authors suggest that since most offices provide lighting levels

of comparable value, within the prevalent range of ambient office lighting there appears to be zero association between ambient illuminance and legibility performance. Nor was there any main effect of lamp type. Age, however, appeared to be a significant factor with younger workers performing better.

Some studies have focused on stress. As suggests earlier (Ruck, 1989b), low and high levels of illumination could be stressful. Basso (2001) conducted a study that focused on the stress-inducing facet of illuminance. His study, however, also involved varying the spectral distribution. This and many other studies dealing with spectral distribution of light sources base their arguments on the evolutionary theory. In essence, the theory argues that early human beings conducted all work under natural lighting conditions, and hence programmed to operate with minimum stress when the ambient lighting follows a pattern similar to the changes in lighting conditions outdoors, through the day. Most artificial light sources have considerably low illuminance as compared to natural light, as well as vary significantly in spectral power distribution as compared to natural light. The development of more sophisticated artificial lights (some closely matching the spectral power distribution of natural light) led many researchers to hypothesize that such light sources would be less stressful to the users. Basso's study was based on the fundamentals of the evolutionary theory, and the hypothesis was that dim and cool-white lighting would be more stressful as compared to bright and full-spectrum lighting. Basso conducted three separate experiments, changing the illumination and spectral distribution in a systematic manner. The first experiment had one subject, a 42 years old male. The second experiment involved five subjects between 5 and 39 years, 3 male and 3 female.

The third experiment had ten subjects between 18 and 26 years, with equal number of male and female participants. Skin conductance was measured as an indicator of stress. Varying numbers of startle trials were conducted. In the first experiment, conducted in an 8ft x 8ft soundproof darkened room, the intensity of light was varied between two extremes – lights off and lights on. Lights on position used two 60W incandescent bulbs. There was significant difference in skin conductance, with the mean conductance at a higher level in the lights off situation. In the second experiment, conducted in a 10ft x 20ft darkened quiet room, subjects were evaluated under dim (300 lumens) and bright light conditions (2500 lumens). Cool-white fluorescent as well as incandescent bulbs were used in the experiments. Results indicated a significantly higher change in skin conductance under low light and cool-light condition. In the third experiment, conducted in a 6ft x 7ft soundproof darkened room, only dim light condition was used. The spectral distribution was varied using cool-white and full spectrum lamps. Results suggest significant difference between cool-white and full spectrum lighting. Cool-white light was associated with higher startle response, especially under low illumination condition. Owing to the low number of subjects in the study, a threat exists to the validity of the findings. However, the study does suggest some association between illuminance and/or spectral power distribution, and stress. The evolutionary theory appears to get some support from other studies dealing with performance. In a field study focused on school setting (Heschong, 2002), the author investigated the association between natural light and performance of school children. She studied all 2nd to 5th grader in three large school districts with a range of daylight conditions in the classrooms. The three districts are located in San Juan, California, Seattle, and Fort Collins, Colorado. In total, data on 8000

to 9000 students in each district was collected. Classrooms with windows were not considered owing to the confounding element introduced by view through windows. Daylight from skylights and roof monitors were measured. Performance measures included test scores on math and reading. Results demonstrated a consistent positive association between increased daylight and improved test scores, other than in classrooms where daylight through skylight could not be controlled, where the association was negative. Despite lack of any consistent evidence in favor of full-spectrum lighting conditions (which is dealt with later), the higher illumination values and wider spectral distribution associated with natural light appears to have some impact on performance, mood, stress, and preference. Morita et al. (2003) hypothesized a relationship between core body temperature and preference for lighting conditions. To know about the quantity and quality of illuminance subjects select during waking period, the author recruited five healthy females around 21 years old, and made the subjects to spend a period slightly more than two days, alone in a bioclimatic chamber. The subjects were allowed to change illuminance and color temperature by using a light box. The author found that subjects' illuminance preference was related to core body temperature. They preferred higher illumination and color temperature during periods of rising core temperature (daytime after waking) and lower illumination and color temperature during periods of falling core temperature (late afternoons and periods before sleeping).

4.1.2 Light direction and shadows

Hill & Bruce (1996) argue that edge-based information may be insufficient for face recognition. They introduce three cognitive models of representation of facial information: edge-based, image-based, and surface-based. Shadows form an important constituent of the later two types of representation models. The objective of the study was to examine the effect of shadows on face perception tasks. The authors used computer generated surface images and varied the lighting directions and viewpoints in the simulated environment. In two phases, they investigated the recognition of familiar faces, first, and then used an identity-matching task to investigate the effect of lighting and viewpoint in more details. The first experiment tested the accuracy of recognition of familiar faces from shape information alone, and the influence of light direction and viewpoint on the recognition task. Light direction was alternated between top and bottom. 12 observers were used for the study, all working in the same department. The computer models used were of people from the same department. Results suggest that in face matching tasks change in light direction as well as viewpoint significantly affect task accuracy. Matching task accuracy was highest for upright top-lit faces.

Braje et al. (1998) conducted a similar study, with the objective to examine the impact of changes in lighting direction and cast shadows on face recognition. The central issue of the study was whether faces are represented in an illumination-invariant or illumination dependent manner. The authors were also interested in knowing about the role, if any,

played by cast shadows. They were interested in knowing whether cast shadows provide any information about surface shape and illumination direction, or whether the impact of cast shadows is negative. They designed a same/ different matching task to study information types stored in short-term memory, more specifically illumination and shadow information. 32 undergraduate psychology students between 17 and 34 years of age were required to view two sequentially presented faces and decide if the faces belong to the same person. Illumination direction was either the same or different for the two faces, which (as opposed to top-bottom conditions in the earlier study) was varied around the sides. In addition half of the faces had cast shadows and half were presented without. Computer models of 40 male and female Caucasians, aged between 20 and 40 years, was used for the study, and all faces were unfamiliar to the observers. Reaction time was measured. The authors found that changes in illumination direction have a negative impact on face matching accuracy. In addition, presence of cast shadows had a negative influence on reaction time, but not sensitivity.

4.1.3 Luminance and Brightness Balance

Boff & Lincoln (1988a), discussing visual acuity, note that (based on laboratory studies involving contrived tasks) acuity increases as background or mean luminance level increases. Background illuminance (and hence the resulting brightness ratio of task: background) affects the adaptive power of the eye. While the recommendations in code vary from country to country, less than 1/3 illuminance of the background is generally considered inappropriate. Luminance increases with increasing illuminance. Increasing

luminance results in greater contrast sensitivity and hence better visual acuity (Ruck, 1989b). Ruck also points out the importance of size and time. Citing previous research works, Ruck reports the association between visual performance involving printed words and gratings, and size, time and luminance. Equal changes in size, luminance or time, when the levels of these variables are high, produces lesser influence on visual performance as compared to when the levels are low. Boff & Lincoln (1988b) reviewed several studies in support of the above association - between luminance and time as they relate to reaction time, in laboratory experiments. Studies suggest that reaction time is inversely related to the duration of flash (or exposure of the object). This relationship, however, holds true up to about 10 m sec, beyond which the duration of exposure (or flash) becomes insignificant. Keeping time constant, as luminance increases, reaction time decreases. The authors also articulate the importance of contrast. In laboratory testing using bar patterns, it has been shown that size and contrast of grating influence the visual reaction time. Reaction time improves with higher contrast.

On a practical note, Ruck (1989b) suggests that the ideal environmental conditions for visual acuity occurs when the background luminance is slightly less than the luminance of the task. She cites previous research that provides more precise recommendations. With illuminance for offices recommended at 500-700 lux (about 50-70 FTC), the optimal environmental conditions occur when the task: luminance ratio for the wall facing the task is about 0.55, 0.48 for walls alongside the task, and 0.5-0.8 for the ceiling. In a review article, Hedge (2000) reports a previous study where they investigated subjects' preference for general and workstation illumination. They found that workers

prefer task brightness between 190-890 cd/m². Ruck (1989a) also points out that in case of visual tasks involving screen-based equipments, luminance and luminance ratios are important variables influencing performance.

4.1.4 Spectral Properties of Light

Objective measurement of spectral qualities chiefly depends on two standard measures: the color temperature of light source, and the Color Rendering Index.

Color Temperature of a source of light is obtained by comparing the spectral distribution of the source with that of the radiation from a theoretical perfect black body. The temperature of the black body at which its spectral distribution closely correlates to the corresponding distribution of the source is regarded as the color temperature of the source. Two sources, however, having the same color temperature could have different spectral distribution. In general, lower color temperatures are reddish, and higher temperatures are bluish. Color Rendering Index (CRI) provides a comparison between a light source and daylight (or a standard lamp). By comparing the spectral power distribution of the source with the corresponding distribution of daylight, it signifies the closeness of a particular lighting quality to that of the latter. The index varies between 0 and 1 and the closer it is to 1 the more natural is the quality of the light source. Light manufacturers provide the color temperature and CRI values for their products. In most field settings the variable of interest is the combined effect of multiple light sources (including daylight). Instruments available for measuring spectral qualities include ones

that provide aggregated color temperature of multiple sources. However, similar instruments for obtaining aggregated CRI values are not available.

Sources in the compendium published by Boff & Lincoln (1988a) suggest an association between spectral distribution and visual acuity. Findings from laboratory studies suggest (where targets are viewed through a small pupil), visual acuity is best in greenish light, and reduces with shorter or longer wavelengths. While spectral composition appears to have some influence on contrived tasks, the authors do not provide any understanding of its implication on more realistic, everyday office tasks. Chapter books reviewing past studies point out that pupil size may explain the association between spectral qualities and behavior. Ruck (1989b) discusses the impact of spectral power distribution on pupil size. She asserts that pupil size could affect performance of works visual in nature. She cites research work where pupil size was studied under different lighting conditions (indirect high pressure sodium and indirect incandescent lights), controlling for the intensity of light, and reports that spectral distribution affects pupil size, and the size of pupil influences the ability to resolve fine details as well as perceive the depth of a field. She also cites other reports where spectral power distribution has been shown to influence non-visual processes, suggesting that environmental information received by the brain influences mood and psychological well-being of human occupants, the spectral distribution being one of important environmental information. Mood, emotional state, muscular activity, breathing, pulse rate and blood pressure are some of the areas believed to be influenced by color. Similarly, in a study on human comfort (Ruck, 1989b), the authors studied subjects under different lighting conditions. They found that artificial

lights that are closer in quality to natural light, as compared to conventional fluorescent lights, are perceived as more pleasant and stimulating, leading to subjects experiencing more relaxation and eye comfort. Ruck believes that this aspect of the lighting environment could be manipulated to influence creativity, productivity and activity.

Discussing occupant comfort, Ruck (1989a) reports that in studies involving different types of light sources (and hence different spectral compositions) it has been shown that light sources that are close in spectral distribution to daylight are regarded by subjects as less discomforting as compared to subjects working under standard (white) fluorescent fixtures. Similar earlier work cited by Ruck assert that full spectrum lighting does have a positive influence on improving performance and reducing fatigue in office work settings.

In contrast to earlier studies, more recent studies have ended up with ambiguous results. Hathaway (1995) designed a study to investigate non-visual effects of different types of classroom lighting. One aspect of the study focused on the association between lighting type and rate of achievement in classrooms. Subjects included 327 students from five schools. Lamps in the classrooms were of four different types: indirect high-pressure sodium vapor lamps, full spectrum fluorescent lamps, full spectrum lamps with UV supplement, and cool-white fluorescent lamps. Achievement measures included scholastic achievement scores from Canadian test of basic skills. A significant difference was found in the post-test analysis, where pre-test scores suggested little difference. Full spectrum fluorescent lighting was associated with more rapid progress in achievement, and high-pressure sodium the least, of the four different lamp types. Possible

confounding variables, however, were not discussed in the study. Veitch (1997) performed a study that challenged the then traditional notion about full spectrum lighting. She designed the study to investigate if one's belief about the full spectrum lighting (based on major propaganda effort by lamp manufacturers) explains the variance between this and other lamp types. In an earlier study with similar goals, of which this study was a replication (Veitch 1991), findings supported the notion that controlling for existing belief, any information (both favorable and unfavorable to full spectrum lamps) resulted in improvement in reading performance and self-reported arousal. Lamp type had little effect, and Veitch believes that the unfavorable information may have led to 'reactance' by the subjects. The replication study tried to avoid this confounding factor by providing four types of information: negative, indifferent, positive, and no-information. Lamp types used for the study included full spectrum (5000K) and cool-white light (4250K). 208 subjects, equally representing both sexes, aged between 20 and 69, were recruited from general public through advertisement. Subject's work experience ranged between 0 to 45 years, and education level from high school to doctorate. Illuminance was controlled at 68 FTC. Measures included preexisting beliefs, performance and mood. There was no significant main or interaction effect of lamp types on performance and mood. Neither the fluorescent lamp types, nor the information provided about the lamps had any impact on mood or performance. During the same period, Knez & Enmarker (1998) investigated hypotheses involving possible mediators between lamp type and the then prevalent assertions on performance. They argued that the color qualities of lamp types first affect the user's mood (again, the evolutionary theory, although the authors do not specifically mention it), and lead to improvements in performance in office environments. They were

also interested in possible moderators like gender. The study involved two fluorescent lamp types, one with a color temperature of 3000K and the other with a color temperature of 4000K. 20 male and 20 female participants recruited from a local college, aged between 18 and 55, were randomly assigned to the two lighting conditions created in an office-like, off-white, environmentally controlled setting. Long-term recall and recognition, free recall, problem solving, judgment, and mood, were measured. Findings suggest no effect of lamp types on cognitive performance. However, analysis of data suggested an association between lamp types and mood, with an interaction effect with gender. The 4000k lamp was associated with best positive mood and least negative mood in females. The 3000k lamp accounted for the same result in males. Knez & Kers (2000), subsequently, hypothesized that lamp types (and the associated spectral qualities) constitute an affective source that is moderated by gender, age or both. 80 participants, matched for gender and age, participated in the study. Mean age for women was 23.3 and 65.2, and for men was 23.9 and 65.5 years. Participants belonged to a local college and a pensioners' club. A neutrally colored office setting with false window served as the setting. Noise was controlled at 35 dB-A, air temperature at 21 C, and illuminance at 50 FTC. Lighting conditions included warm-white light (3000K) and cool-white light (4000K). Authors measured mood, perceived room lighting estimation, short-term recall, long-term recall and recognition, and problem solving tasks. Results suggested that lamp type had an influence on participant's mood, but only the negative mood. Association with mood was moderated by age, but not gender. And younger participants performed better than older participants in cognitive tasks. Hedge (2000), in a review article, cites a Canadian study that found similar effect of light on mood, but not on performance. The

study investigated the association between lamp types, and learning, health and attitude of children in grade 4 to 6. There were no significant findings on health or learning measures. There was a significant difference on comfort ratings – more positive for warm white light as opposed to cool white light. They found little evidence to support the beneficial effect of daylight simulating lamps. Knez (2001) study, however, found some favorable results. Investigating into the impact of lamp type on mood and cognitive performance, Knez recruited 108 high school students (from a single school), with similar educational background, aged about 18 years, and divided equally between the sexes. Participants were assigned randomly to three lamp settings, in a neutrally designed and colored windowless chamber: warm-white (3000K), cool-white (4000K), and artificial daylight white-light (5500K). Knez measured mood, perceived room light, short-term recall, long-term recall and recognition, and problem solving tasks. For short-term recall tasks warm-white lamp was found better, so as in problem solving. Gender acted as moderator in long-term memory tasks, with males showing variance in the different lighting conditions.

A different line of inquiry, on visual clarity, however, came up with significant findings. Vrabel et al. (1998) looked into perception of visual clarity as opposed to performance under different light sources. The authors describe visual clarity as a combination of color rendering, color discrimination, color preference, and border sharpness. They targeted light sources that were, then, conventionally used in typical commercial environment, and designed an experimental setting involving a room with white walls and ceiling, and gray floor. Illuminance was controlled at 50 FTC on the subject's desk, and 30 FTC at the

visual clarity scene (in front of the subject). Lamp types included cool white fluorescent (4100K, CRI 62), energy efficient tri-phosphor fluorescent (4100K, CRI 82), high grade halophosphor fluorescent (5000K, CRI 91), clear metal halide (4200K, CRI 60), and white high-pressure sodium (2700K, CRI 80). Subjects included 29 student volunteers from an introductory architectural engineering course, eight females and 21 males. Average age was 21. The visual clarity test involved a seven point semantic differential rating scale that included scales from: visually warm to visually cool, sharp edges to dull edges, bright to dim, colorful to colorless, clear to hazy, natural to unnatural, like to dislike, pleasant to unpleasant. Analysis of variance demonstrated a significant difference arising out of different lamp types. High-grade halophosphor fluorescent and energy efficient tri-phosphor lamps (both notably higher in CRI) were associated with the positive ends of the scales.

Possible reasons for the inconsistent results of recent studies were articulated by Veitch & McColl (2001). The authors conducted a review of all literature published between 1945 and 1998. All were pertaining to the effects of spectral distribution on perception, cognition and other behavioral outcomes. The authors focused on the claims that full spectrum fluorescent lamps improve visibility, reduce hyperactivity, improve academic performance, reduce fatigue in office workers, improve health, and similar other past claims. In general, the authors cast doubt on the outcomes of most of the studies reported, and underscore the problems associated with the reliability and validity of the studies, thus leading to confounding results. The problem areas highlighted include:

- Most studies dealt with illuminance where luminance (as descriptor of stimuli) should have been the appropriate measure. Thus, the luminous conditions experienced by the participants are unknown.
- Lamp efficacy changes between lamp types. Thus in a single experiment when the lamps are changed (and thus the output) the change in output level could have led to some of the effects shown.
- Luminaries differ in the way they absorb UV radiation. Research reports were not consistent in describing luminaries used in the study.
- The presence or absence of windows in the experimental setting has not been consistently reported, especially in field studies.
- Previously used magnetic ballasts behave very differently than the recently developed electronic ballasts. Also, the phosphor compounds used in fluorescent lamps vary considerably in their spectral output and decay time for that output. Lamp outputs, thus, vary chromatically as well as in overall luminance. There is lack of information in the studies regarding these confounding factors.

4.1.5 Factors influencing screen-based tasks

Dillon & Emurian (1996), in a review article, outline some important variables for screen-based tasks. The paper surveyed human factor literature related to visual fatigue resulting from use of VDU's. The key variables identified by the authors include:

- Viewing distance: reports of studies in the early 1990's where subjects were allowed to adjust viewing distance shows that viewing distance of greater than 50 cm was found to be preferred by all subjects.
- Color of the VDU character and background: with improvement in technology, this may not be an important variable, since conventional screen-based work today allows for user adjustment of this variable. Nevertheless, studies have not found any significant relationship between color of character and background and fatigue.
- User demographics: studies that found association between visual fatigue and demographic variables report such variables as subject's level of education, years of work experience, marital status, age, and gender. Age and gender, however, are the more common demographic variables studied, although without any consistent findings.
- Duration of VDU use: there appears to be an association between duration of use and visual fatigue. The association is not linear and increases in magnitude with increasing duration of work.
- Glare and physical feature of the VDU: glare from VDUs have been hypothesized to induce fatigue (briefly discussed earlier). Interestingly, studies have not demonstrated consistent significant results. In contrast, inadequate lighting in workstation has been shown to have a greater influence on symptoms of fatigue. The explanation seems to be in the fact that illuminance influences the use of key boards, source documents, and other media that must also be viewed during VUD

tasks. High illumination levels in workstations have been found, however, to induce fatigue.

Boff & Lincoln's (1988b) compendium outlines some factors based on earlier studies in this area (that may not be relevant to this study) as important factors influencing visual task performance including display screen symbol luminance, display resolution, symbol size, viewing angle, vertical resolution, CRT scan line orientation, CRT symbol size and resolution, CRT symbol size and stroke width, CRT symbol spacing, display element size. Some variables of pertinence, discussed in literature, are outlined below.

One confounding factor associated with studies on screen luminance is pointed out by Duffy & Chan (2002). The fact that VDU luminance decreases over time (although the magnitude of decrement is not commonly agreed upon, create some reliability problems in experimental as well as field studies.

4.1.5.1 Flicker

Flicker is caused owing to the refreshing rate of Cathode Ray Tube based screens (Ruck, 1989b). Ruck suggests that flicker could be associated with behavioral outcomes like eyestrain, that in turn influence visual performance. Ruck (1989a) cites previous research to emphasize the association between screen flicker and eyestrain, and reports that based on experimental results it is likely that about 40% of people working on screens would consider a flicker frequency below 60 Hz as uncomfortable. Also, in comparison with non-flickering light sources, users of screen based instruments find fluorescent lighting

less than 69 Hz as stressful. In such cases it has been shown that the accuracy of task decreases and time required for task completion increases.

Boff & Lincoln (1988b), however, suggest that the presence of flicker may have been overstated in the large volume of studies in this area. Phosphors in CRT, according to the compendium editors may result in flickers being less prevalent than as predicted in laboratory studies.

Studies of flicker have not been limited to VDU based tasks. Improvement in lamp technology (through the use of high-frequency electronic ballasts) that has changed the flicker rates in fluorescent light sources have led researchers to hypothesize association between flicker rate and behavioral outcomes outside the task performance domain.

Kuller & Laike (1998) designed such a study. The underlying argument was that flicker from fluorescent lamps are associated with visual discomfort and stress. They based their hypothesis on the arousal theory that assumes optimum performance at moderate level of arousal. The authors hypothesized that arousal from flicker would increase speed but reduce the accuracy of task performance (owing to stress). 19 males and 18 females

between 21 and 50 years, from a wide range of occupation, were recruited for the study.

The experiment was conducted in an office-like setting with two fluorescent lighting conditions – one with traditional magnetic ballasts, and the other with electronic ballasts.

Measurements recorded included EEG and EKG, affect, visual discomfort, headache, feeling of stress and fatigue, personality, and subject's performance on a numerical proofreading task. Findings suggest that magnetic ballasts were associated with report of

less pleasant environment. Interestingly, however, both conditions were perceived as low in flicker content (supporting Boff and Lincoln's assertions mentioned above), although light provided by the electronic ballast was slightly favored. On a seven-point subjective flicker score rating scale, no subject assigned a score above 4. In fact, an interview with subjects indicated that none of them were aware of the differences in lighting modulation. No main effects were found for visual comfort, head ache, and feeling of fatigue, or on task performance.

4.1.5.2 Screen Position

Screen position, as suggested earlier, may be an influential factor influencing performance, especially for fixed screen positions. Aaras et al. (1997) set out with the task of comparing postural loads during VDU tasks. They investigated three posture types that involved supporting and not supporting the forearms on the tabletop, sitting and standing positions, and sightline to the center of the screen at an angle of 15 and 30 deg below horizontal. 17 male and three female subjects (all experienced VDU workers) participated in the study. In total five positions were studied: sitting, sightline angle 15, forearm support; sitting, sightline angle 30, without forearm support; sitting, sightline angle 30, with forearm support; standing, sightline angle 15, without forearm support; standing, sightline angle 30, without forearm support. Load on the musculoskeletal system was measured. Results suggest that the least stressful condition involved sitting work with a sightline of 15 deg, supporting the forearm. Interestingly, angle of vision did not produce significant results. Jaschinski et al. (1998) designed a study to find the most comfortable working position. 22 employees were recruited for the study in eight

identical workstations. Eye level above floor, viewing distance from eye to screen, inclination of VDU screen surface, height of reference point on the VDU, and table height of keyboard were varied and measured. Findings suggest that high screens result in greater eyestrain as compared to low screens. Change from far to near viewing distance produced larger increase in eyestrain when screen is at eye level. Subjects showed a preference for a viewing distance between 60 and 100 cm, and a vertical inclination of 16 deg. A succeeding, identical, study by the author (Jaschinski et al., 1999) involving 38 operators who worked for a full working day in an experimental setting, found that screens at about 66 cm induced more reported strain than screens at about 98 cm.

Liao & Drury (2000) performed a study to demonstrate the interactions between workplace, work duration, discomfort, working posture as well as performance in a 2 hour typing task. Six college students participated in the study. Keyboard height was set to three different positions: low (sitting elbow height), medium (60 mm above sitting elbow), high (120 mm above sitting elbow). 12 levels of work duration was measured, with the dependent variables including joint angle, postural shift, musculoskeletal discomfort, fatigue, performance. Findings suggest that medium height was associated with the lowest discomfort, partially supporting the idea that postural discomfort might have an effect on typing performance.

4.2 Variables influencing auditory task performance

4.2.1 Reverberation Time

Not many studies are reported on reverberation time. The reason could be the difficulty and expense involved in varying the reverberant characteristics of any space, which is primarily dependent on the surface materials and the room volume. The few studies reported in literature clearly articulate the relationship between reverberant characteristics of the acoustical environment and task performance. Payton et al. (1994) conducted a study with the primary objective to study the relationship between speaking styles (clear and conversational speech), acoustical characteristics of the setting, and listening abilities of normal speaking and hearing impaired listeners. The study involved three types of physical settings with varying reverberation times: an anechoic chamber (non-reverberant), a living room (RT of 0.18 s), and a conference room (RT of 0.6 sec). In addition the ambient noise level was also varied through the addition of speech-shaped noise to the sentences (stimuli) at different signal to noise ratios: 9.5dB, 5.3 dB, and 0.0 dB. Signal to noise ratio (S/N) is the ratio of the level of the incoming signal (stimuli) and the background or ambient noise. 10 normal hearing subjects between age of 18 to 40, and two hearing impaired subjects around 50 years of age participated in the study. The primary measure was the speech intelligibility score. Results suggested that the combined effect of reverberation and noise was more than the individual effects. A significant interaction between noise and reverberation was evident. As RT increases, the difference

between the scores of the noisy conditions increased from 24% to 39%. Finally, they concluded that clear speech was more intelligible than conversational speech.

These experimental findings are also supported in field settings. In a review article (Picard & Bradley, 2001) focusing on acoustical impediments to learning, the authors cite past literature in classroom settings. They point out that the interaction between excessive noise and reverberation in classrooms has a considerable impact on speech recognition, and hence academic achievement. They summarize studies to suggest that ambient noise, in general, is more harmful than reverberation. They were referring to classroom settings where noise levels are generally much higher than recommended in practice. They cite previous studies to point out that in case of speech intelligibility (studying the impact of reverberation and ambient noise over the entire range of values that one is likely to witness in field situations) it was found that the negative impact of excessive noise was more than that of excessive reverberation. Having pointed this out, the authors also underscore the fact that reverberation constitutes an important environmental factor in classroom performance. They assert that RT in excess of 0.7 s in classrooms could impede performance in speech intelligibility. They explain the phenomenon by saying that increased reverberation result in an increase in the area within a classroom where late reverberant sound mask the original sound and early reflections that combine to produce highly intelligible speech. They, too, suggest that the combined effect of high noise and reverberation could be more than the individual factor alone, suggesting a significant interaction between the two factors.

One important property of reverberation time pointed out by Picard & Bradley (2001) is that users may not be very sensitive to minor changes in RT. Thus, minor variations from suggested optimum RTs may not result in any detrimental effect. In rooms involving speech tasks, it is commonly believed that RT be reduced as much as possible. On the contrary, the authors underscore the positive impact of reverberation (especially early reverberation) in reinforcing speech signals (and hence resulting in better intelligibility), and increasing the speech level (better audibility). Very low reverberation, they believe, could lead to circumstances where incoming speech level is not sufficiently high, resulting in reduced audibility of fainter high-frequency consonants. On the other hand, excessive reverberation could acoustically smear the signal reaching a student, making it difficult to perceive the gap between two words in case of hearing impaired as well as normal hearing students (Towne & Anderson, 1997).

4.2.2 Noise Level

Noise has effects on comfort, mood, and other behavioral outcomes. Conditional effects of the general characteristics of the environment on occupants' satisfaction with the acoustic environment has been cited by Lawrence (1989b). Lawrence cites previous research where they tested the effect of ambient noise level on occupant's satisfaction in a residential suburb in Paris. They reported that the people's willingness to tolerate certain level of ambient noise is conditional on the general character of the neighborhood. More specifically, people were willing to tolerate ambient sound level of 5 dB higher where they are satisfied with the character of the neighborhood. On the flip side, when

people are dissatisfied with certain aspect of the environment, they are more likely to vent their dissatisfaction through complaints of excessive noise.

Ambient noise level is also reported to influence task performance, but the association is conditional on the level of complication of the task (Lawrence, 1989b). Lawrence, based on experiments in laboratory settings, reports that in case of monotonous tasks, high ambient noise level may improve task performance by increasing the arousal level of the subject. On the other hand, if the task entails high cognitive demands, higher level of ambient noise may impede task performance by being distractive. Lawrence also discusses the moderating effects of cultural variables. In situations where some changes are initiated – as in providing greater attention to occupant's complaints- it is noticed that the subjects perceive some improvement in the environment despite the absence of any change in the noise level.

Background noise is a major impeder in schools. Towne & Anderson (1997) discuss some important variables affecting performance in schools. One is the background noise that masks needed speech information. The other is distance between the speaker and listener (which is partly applicable in courtroom settings mainly when attorneys are the speakers). They base their assertion on a classroom study that measured speaker listener distance on speech recognition while keeping other variables constant (S/N ratio 6dB, RT at 0.45s). Mean recognition scores decreased from 89% to 36% as the distance was increased from 6 ft to 24 ft. Gifford (1997) reports certain key aspects of the office environment that influence behavior. He suggests that impact of noise on productivity is

unknown, but occasionally noise has been shown to improve performance (in agreement with Lawrence, 1989b). He highlights some possible moderators that might explain the conflicting findings on productivity. Those include task characteristics (cognitive, vigilance, motor, and social), task complexity (simple versus complex task), as well as task intensity (single task versus multiple, simultaneous tasks). He contends that tasks that are more susceptible to noise are those that involve multiple sources of information and more than one task at a time. In multi tasking environments, noise affects the task of lesser importance as compared to the more important ones. Motor tasks, however, are not usually affected by noise. Gifford also suggests that personality may moderate the association between noise and behavior. When noise hinders performance (as opposed to the desirable characteristics of masking in some situations), Gifford contends that relevant (meaningful) sound have a greater negative impact as compared to irrelevant sound. The presence or absence of control over blocking the sound source is also an important factor. Meaningful, uncontrollable intruding sound is more likely to be perceived as noise. This notion is supported in Picard & Bradley's (2001) review of classroom studies. They cite shared classroom experiments of the 1960s and 1970s, where the intruding speech from adjacent classrooms (similar in spectrum and level to the desired speech, as well as meaningful), were found to be more distracting than an equivalent level of neutral noise. Discussing further on classroom performance and noise level, they cite studies that show that classroom noise result in significantly lower performance on mathematics and alphabet tasks, as also a higher activity level in case of hyperactive children. It has been shown that chronic exposure to high noise level in children lead to significant deficit in speech perception and reading skills.

Another issue about background noise is whether it is continuous or not. Ainsworth & Meyer (1994) designed a study to test the effect of noise (continuous and intermittent) on the perception of plosive-vowel syllables. Subjects included six listeners, including one German and five Native French. The stimulus was a database of 300 speech samples. The stimulus was presented in the two types of noise conditions. Results suggest that increasing noise level affected performance, but the impact was significantly less in the case of continuous background noise.

Gifford (1997) cites studies that show that intermittent noise cause mainly temporary setbacks. Predictability of intermittent noise is more important. Thus, unpredictable, uncontrollable, meaningful sound is potentially most harmful in office settings. Also, noise has been hypothesized to affect performance even after the noise source has ended. A safe general conclusion offered by Gifford is that performance is variable under noisy conditions. He also suggests that actual performance in offices may not change with noise.

The topic of noise annoyance is further articulated by Sailer & Hassenzahl (2000). They contend that most noise studies have been conducted in high noise settings, and low level noise could also hinder performance and have negative effects on concentration, productivity, and working capacity (within the broader definition of noise as unwanted sound). They introduce the concept of ‘representative noise event’ as opposed to a general noise situation, asserting that even at general low noise level, some reference

noise event could lead to the feeling of annoyance, and in turn affecting performance. They collected sound level measurements from field settings and distributed a specially designed questionnaire (in the same settings) to 116 subjects, including 71 university employees, 23 bank employees and 22 employees from other offices. There were 63 women and 53 men, with a mean age of 35.9 years. Office settings varied from open plan to more conventional single and shared rooms. Results suggest that reference noise events could be generalized to overall annoyance from the noise situations in workplaces. Similarly, Brooks (2003) also points out that even low-level noise (generally not studied in earlier works) can have many ill effects including stress. He points out a further complication arising out of the fact that even in the presence of high background noise, sound signals of lower levels could be audible since the ability to hear is a function of spectrum, location, time, and directionality of human hearing. Thus, annoyance is probably most influenced by predictability - the knowledge of impending noise and its duration provides some control.

4.2.3 Signal to Noise Ratio

Boff & Lincoln (1988b) cite experiments that articulates the importance of signal (speech power) to noise (noise power) ratio in speech recognition tasks. They report that the recognition of speech improves with increase in the signal to noise ratio. Further, they report that this ratio remains more or less constant for noise levels between 35 and 110 dB (this constancy, however, is reported for speech to be just barely intelligible, which

may not be the focus of attention in this study). However, speech level above 100 dB results in a decrease in speech intelligibility.

In field studies, the importance of S/N ratio has been shown in classroom studies (Towne & Anderson, 1997). They report that in classrooms where teacher's voice is presented 10 to 15 dB over background noise level through amplification, a significant improvement in academic achievement and other behavioral benefits have been shown.

Bradley et al. (1999) studied the combined effects of a wide range of S/N ratio and room acoustics conditions on speech intelligibility. They used a synthesized sound field to simulate different reverberation time and S/N ratios using modern technology. The objective was to determine the relative importance of S/N ratio and reverberation time on speech intelligibility over a relatively broad range of both variables. They chose acoustical conditions that are representative of conditions one might encounter in field situations. Ten adult subjects between 20 to 62 years age participated as subjects. Subjects were made to sit in a synthesized sound field in an anechoic chamber where the S/N ratio, the reverberation time, or both could be varied using computers. The authors measured speech intelligibility scores (percentage of correct response) from four lists of 50 words, where the subjects had to identify the initial consonant of each test word. Overall level of speech was controlled at 55 dBA, and ambient noise level was simulated to match an NC 40 shaped spectrum. 16 different variations of the acoustical condition were tested consisting of four different S/N ratio and equal number of reverberation time. Results suggest that both S/N ratio and reverberation time influence speech intelligibility.

However, the influence of S/N ratio was significantly larger. The authors concluded that the importance of reducing ambient noise is much more (and should be handled first) as compared to reducing reverberation time. They suggest a S/N of equal to/more than 15 dB as acceptable.

In certain situations the duration of signal also matter, over and above the S/N ratio. Boff & Lincoln (1988a) point out the importance of signal duration for audibility, albeit in a different context. They point out that the duration of signal as well as the signal to noise ratio influence the detectability of a tone in noise. The important benchmark appears to be about 200 m sec. Below this duration sensitivity decreases linearly with duration. With lower duration of signal, the signal to noise ratio needs to be higher to be able to make the tone detectable.

Manipulating background or ambient noise provides leverage on the denominator of the S/N ratio. The numerator (signal strength) is also of importance, and easily controlled through electronic reinforcement systems. However, owing to reasons mentioned before, electronic reinforcements do not help in all circumstances. It is, thus, important to understand this factor in performance related to auditory tasks. Lawrence (1989b), discussing speech and hearing tasks, explains that the possibility of speech communication (two way, face-to-face, or one way) between people is dependent on several factors. One is the loudness of the sound received by the recipient. A second factor is the clarity of speech (which is influenced by several factors including reverberation time, ambient noise level, and long delayed reflections). A third factor is

the characteristics of the transmission path between the two (or more) people. A final factor is the hearing ability of the listener, which is discussed in a separate section in this chapter. As regards to loudness, Boff & Lincoln (1988a) outline several factors that affect loudness of a sound source: sound pressure level, frequency, band width, duration, presence of masking stimulus, tone intermittency, interaural phases, and monaural versus binaural presentation. They point out that sound pressure level of the source is one of the key variables affecting the perception of loudness. Loudness increases with increase in sound pressure level. This association, however, is conditional on the frequency of the signal. At any given sound pressure level, sound at the middle frequency range are perceived as the loudest and it decreases on the lower and higher sides of the frequency range. In situations involving unaided human speech as the source signal, Boff & Lincoln (1988b) define speech pressure as “the force exerted by the sound wave at a specified location with respect to talker, usually 1m, and normal to the line of the speaker’s lips” (p-1778). The speech pressure level, according to this definition ranges from 46 dB for whispering to 86 dB for shouting. The pressure range for normal speech ranges between 60 to 65 dB. In addition, the intensity of human speech is frequency sensitive. They report that human speech intensity is greatest for frequencies between 100 and 1000 Hz after which it steadily declines.

The issue of signal frequency has been touched upon by several sources in earlier discussions, and warrants a brief discussion. Specifically as it relates to hearing (rather than speaking task), Boff & Lincoln (1988a) highlight frequency as an important factor influencing audibility (ability to detect sound signals). They report that the threshold for

audibility is lowest (sensitivity is highest) at around 4000 Hz. The threshold increases (sensitivity decreases) as one moves away from 4000 Hz on the lower or higher side of the frequency band. The importance of frequency was demonstrated by Schijndel et al. (2001) in a study that focused on auditory coding and speech perception. They studied several factors including intensity, time and frequency, and varied each factor to observe their impact on speech perception. Subjects included 12 normal hearing listeners between 20 and 63 years of age, and 26 sensorineurally hearing-impaired listeners between ages of 24 and 67. Sentences and words were presented to the subjects with variations in intensity, time, and frequency, which were artificially distorted after wavelet coding. Authors measured detection threshold of the subjects. They found that distorted coding of spectral information (frequency) of source signal had the largest influence on speech intelligibility, with little evidence in support of the other factors.

A final, but important, factor is the sensitivity of human speech and hearing to directions. Higher frequency components of human speech are directional and significantly affect listening conditions depending on the location of speaker and listener. Human hearing, too, is sensitive to direction of sound source (Brooks, 2003).

4.3 Interaction Studies

Temperature alone has been the subject matter of some literature. Gifford (1997) states that the association between temperature and performance is moderated by task complexity; more complex the task, more the performance is negatively affected with

higher or lower temperature. Based on empirical research, he offers a recommended temperature of 80 deg F for vigilance and dual tasks, and slightly lower temperature for tracking and learning tasks. Length of time is also a moderator; lengthier work hours involving cognitive tasks are affected by temperature above 87 deg F. Also, work involving heavy clothing requires cooler temperature (65 deg F), and light clothing requires warm temperature (78 F). Field studies of offices show that 70 to 80 deg F, under typical humidity and clothing conditions, define the comfort zone. Hedge (2000), quoting a Finnish study on offices, also arrives at a similar recommended range of 21 to 23 deg C. He notes that variations in humidity (up to 30%) had little impact on worker satisfaction, where as temperature variations from an optimum of 20 deg C leads to rapid change in satisfaction level.

Several multi-parameter studies suggest significant association between environmental factors and user behavior. Hygge & Knez (2001) designed a study to investigate the interaction between noise, heat and illuminance on attention, memory and problem solving. Subjects include 128 participants between 18 and 19 years of age recruited from a local high school. There were an equal number of men and women. The authors designed eight experimental conditions; two noise settings (250 Hz noise at 38 and 58 dB from a heat exchanger), two heat settings (21 and 27 degrees Celsius), and two settings of illuminance (30 and 150 FTC at 3000k color temperature). Measurements were taken on attention, problem solving, long-term recall and recognition, short-term recall, and affect. As suggested by Gifford (1997), results varied depending on task type. The findings support an interaction effect between noise and heat on recall of text (heat affected recall

at high noise level, but showed opposite influence at low noise level). There was an interaction between noise and light on free recall (at low illuminance recall was high with noise, at high illuminance recall decreased with noise).

Takahasi et al. (2001) used city noise to study the combined impact of impact of noise and luminance on cognitive performance and feeling of fatigue. Six healthy male students between 21 and 23 years participated as subjects. They performed simple addition tasks for 60 minutes on a computer screen, in four experimental conditions: high luminance condition ($90:7 \text{ cd/m}^2$) without city noise, low luminance condition ($20:7 \text{ cd/m}^2$) without city noise, high luminance with city noise, and low luminance with city noise. Ambient illuminance level was kept constant at 50 FTC. Noise introduced was from recorded road traffic at 67.7 dB-A. Self reported fatigue scores (projection of physical disintegration, concentration difficulty) increased under noisy conditions. Even mild level of noise was found to be a stressor in high luminance conditions.

Knez & Hygge (2002) studied the influence of light color and meaningful noise (speech) on cognitive performance. Light color was varied by using warm white (3000 K) and cool white (4000 K) lamps. Illuminance was kept constant at 50 FTC. Noise conditions included silence and meaningful, irrelevant, conversational speech. Irrelevant speech was fed through a loud speaker at 66 dB. Subjects included 96 (48 male and 48 female), 18 year olds, from a local high school, and were exposed to four experimental conditions. The investigators measured attention, long-term memory recall and recognition, short-term memory recall, problem solving, and affect. Results suggest a main effect of noise;

subject's long term memory recall was better in silence condition. There was a main effect of lamp type; long term memory recall was better under warm-white conditions. Gender did not act as a moderator. The authors have not reported any interaction effect between light and noise conditions.

Pellerin & Candas (2003) studied the combined effect of noise and temperature on subject's estimate of the thermal and acoustical environment. They used a questionnaire using analog scales to record subjective response on thermal sensation, thermal comfort estimate, thermal preference, acoustic perception, acoustic comfort and acoustic preference. 54 male and 54 female subjects, all Caucasians, with a mean age of 23.5 for males and 22.9 for females participated in the experiment. Subjects were divided into nine groups, each group comprising six males and six females. Noise was a recorded noise of a fan (pink noise in spectral composition). Four groups started from a thermoneutral but noisy environment, and four groups started from a cool and quiet or a cool and warm condition. One group was used as a control group. The experiment lasted two hours. During the first hour the subjects were allowed to change the environmental setting once every ten minutes. However, any change in one parameter triggered a corresponding, predetermined, change in the other parameter (since the authors contend that noise from mechanical systems and thermal conditions are related). The second hour included a steady condition. The authors found a combined effect of noise and temperature in warm conditions. They also suggest that women are more sensitive to thermal aspects as compared to men.

Appendix V

5.1 Questionnaire Format

Questionnaire Format: Sudman & Bradburn (1982) support a ‘booklet’ format as opposed to other formats for questionnaire design. They cite several reasons in support of their contention. They argue that the chances of questionnaire pages being lost or misplaced is less in booklet formats. It also makes it easier for interviewers and respondents to turn pages. Moreover, double-page formats make it better to record data on multiple events and persons. Finally, they assert that booklets look more professional and consume less paper. Accordingly, the final questionnaire was created in a double page format and (in the absence of better means of binding for a three-page questionnaire) stapled along one side to resemble a booklet format.

Answer/Scale Format: Sudman & Bradburn (1982) suggest that answer choices should be listed vertically. This, they suggest, makes it easier to read, and leaves ample white spaces on the page that helps in rendering a less threatening look for the questionnaire pages. However, they also point out that in cases where several questions use identical answer categories, aligning the answer choices horizontally, rather than vertically, makes better sense in terms of saving space. According to them, interviewers as well as respondents experience little trouble with the horizontal answer format. After trying out

several page formats for the rating scales it was decided to use a horizontal format for the rating scales.

Questionnaire Length: How long the questionnaire should be, is yet another important issue discussed in literature. The general assertion has been to keep the questionnaire short. While there are no formulas for the length of a questionnaire, it has been suggested (Sudman & Bradburn, 1982) that the saliency of the issues addressed in the questionnaire, to the respondents, should dictate its length. More salient topics, according to the authors, could make longer questionnaire feasible. In such cases, they believe that questionnaires from 12 to 16 pages are possible. On the other hand, questionnaires on less salient topics should be kept short, within two to four pages according to their recommendation. While the questionnaire length of six pages (three double-sided pages) in this study could be considered long, several factors suggested that the length is tenable. First, the questionnaire was administered by the investigator, and was not a mail questionnaire. That introduced a social angle to the process, which was assumed to address some of the pitfalls associated with long questionnaire. Second, the topics dealt with in the questionnaire are highly salient to the respondents. Work places are important to people since they spend most of their time in those settings. Further, the importance and gravity of work conducted in courtrooms, makes issues of performance in the courtroom highly salient to its users. Finally, all target respondents were well educated, and it is believed (Sudman & Bradburn, 1982) that longer questionnaires are feasible when respondents are well educated.

5.1 Question Design

Starting Question: An issue in questionnaire interview is the first question (Sudman & Bradburn, 1982). The very first question should be easy, salient, and non-threatening, leaving the difficult or threatening questions towards the end of the questionnaire. A part of the reason for this strategy is to help the respondent focus on the issue of discussion, and a way of doing it is to ask general and easy, but salient question to the respondent at the beginning. That also provides the respondents to express their views on topics of importance to them.

In the current study, a similar benefit is accorded through semi-structured, open-ended interview with participants that preceded the survey in case of federal courthouses. The semi-structured interviews generally touch upon a wide range of topics, and provide ample opportunity to the respondents to air their concerns about aspects of the building salient to them. It is, hence, assumed that the preceding interview increases the validity of the survey data, and that the interview helps the respondents focus on the issues of interest to this study. In case of state superior courts, a similar unstructured discussion occurred with the key players before the questionnaires were administered. Some respondents in the state courts did not, however, come in contact with the investigator. To overcome the difficulty arising from such a situation, the first page of the survey made it clear to the respondents that the last section of the questionnaire provides space for comments on issues bothering them. The fact that many respondents did use the spaces

provided to provide comments gives some assurance that the lack of personal contact may not have created any problems.

Order Effect: One major issue highlighted by survey design literature is the influence one question has on other responses in the questionnaire, thus reducing the validity of the data. More specifically, specific questions on an issue, preceding a general question, appears to influence the response on the general question. Sudman & Bradburn (1982) suggest that in personal interviews, as opposed to mail questionnaire, the questions could be arranged from the more general to more specific (use of funnel questions).

In this study, all questions in the questionnaire are at one level. There are no second order questions within any block of questions. As point out by some authors (Sudman & Bradburn, 1982), the order effect is more pronounced within blocks of questions. Little order effect has been found by changing the order of the blocks of question. It, thus, might be assumed that each block of question, and the questionnaire as a whole, is free of order effect arising from close proximity of related questions that vary in specificity.

A different kind of order effect is the response order effect. Discussing recency effects and primacy effects, Krosnick (1999) points out how the choice of response, from among a list, is affected by whether the list is visually presented or verbally presented. Krosnick attributes this problem to the phenomenon of satisficing in psychology literature. In essence, while satisficing, a respondent chooses the first reasonable response from a list where as, ideally, the researcher would like to obtain the most appropriate from the list of

alternatives. This effect, as Krosnick points out, is different for categorical and ordinal responses. In ordinal scales, as is the case in this study, a respondent while satisficing would select the first one that is acceptable from among the scaled response categories rather than looking for the most appropriate, leading to a primacy effect irrespective of whether the scale is presented verbally or visually. Thus, the ratings provided by respondents, if satisficing, could be affected depending on the direction in which the scale is presented (from the most to least or vice versa). However, it has also been shown (Krosnick, 1999) that the primacy effect is stronger for people with more limited cognitive skills. It could be reasonably assumed that target respondents in this study possess high cognitive skills, which should reduce the possibility of primacy effect arising out of the ordinal response scale used in this study.

Response Sets: A matter of concern in survey design is the creation of response sets. Different authors have discussed various forms of response sets. Sudman & Bradburn (1982) point out that in instances where all questions share a common response format (like agree to disagree) with identical rating categories, the chances of the respondent answering every section in a particular pattern increases. One way the survey questionnaire possibly avoided a response set problem is by changing the labels of the scale. Rating labels in this study was changed depending on type of question being asked. However, a large number of questions did share the same response categories. Also, all scales in the questionnaire have 7-point ordinal categories, and the possibility that the visual similarity between locations on the ordinal scales could have lead to response sets could not be ruled out. Survey results however, suggest that this problem may not have

occurred since most respondents appear to have thoughtfully chosen the appropriate response, which is evident in the change in response between questions, and corrections made by respondents in many cases.

Scale Number and Labeling: It has been pointed out by numerous authors that the labeling of the scale affects reliability and validity of the data. Out of several choices, including text-labeling the endpoints with numbers assigned to intermediate positions, or graphical representation of intermediate points, Krosnick (1999) points out that labeling all points with words significantly improves reliability and validity since it provides meanings for intermediate points. Fowler (1995) provides a detailed discussion on the issue. He points out that two prominent issues need to be dealt with while dealing with scales: 1) the number of categories to offer, and 2) whether to use numbers or adjectives (labels) for positions on the scale. He suggests that more categories are better than fewer categories for obtaining valid information. In the same note he also suggests some limiting factors to the number of categories. Based on experience in questionnaire-based research, it is observed that more than 10 categories offer little new information. According to him, five to seven categories appear to provide a meaningful set of choices to a respondent. For labeling response categories, Fowler argues in favor of adjectival scale, as opposed to numerical labels. The former provides a more consistent calibration.

A related issue is regarding the polarity of the numbering system. The numbering system in the questionnaire (in the 7-point scale, for instance) could be from 1 to 7, 0 to 6, or from -3 to +3. Krosnick (1999) points out that changing the numbering scheme affects

the way people respond to a question. He suggests that the scales could use only verbal labeling, or the numbering system should reinforce the meaning of the words. Fowler (1995) also favors providing adjectival labels for all response categories to overcome this problem. With seven points in the scale, providing meaningful adjective labels for all response points posed little problem. Finally, text labels for responses create problem in cross-cultural studies where word meanings change between groups (Fowler, 1995). In this study it could be assumed that users of courtrooms have a more or less uniform vocabulary, and belong to a relatively homogenous cultural group as compared to groups referred to by Fowler in international or cross-cultural studies.

“No Option” Response: Many questionnaires use a ‘no options’ or ‘don’t know’ response for each question. The belief has been that for questions where respondents have no knowledge to provide a response or are not familiar with the topic or have no particular feeling about a topic, a no-option option helps in reducing response that are given arbitrarily. While it is generally believed that no response options improve the quality of data, Krosnick (1999) cites increasing evidence against the reliability of such a response category. Ambivalence about response, difficulty in understanding the question or answer choices, and many other situations seem to lead to respondents reporting no options. Using the satisficing theory Krosnick argues that low optimizing ability, low motivation, and high task difficulty could lead a respondent to this response category, and not providing a no-option answer choice could lead to greater optimization. Furthermore, as Fowler (1993) suggests, respondents find answering difficult as the object of the study distances from their immediate lives. From such a perspective, most questions in the

questionnaire in this study pertains to environment that respondents live through on a regular basis, and questions related to tasks that they perform as a part of their regular duty. A no-option or don't-know response category, thus, was not justified. The questionnaire in this study did not include a no-option or don't-know answer choice in light of the findings from recent psychological studies, as mentioned above. The questionnaire, rather, used a "N/A" (not applicable) option for situations where users are being asked to evaluate the setting for tasks they do not perform (an example is asking a security staff about examination of evidence, which is not a task performed by this user type).

5.3 Testing for Reliability

Literature suggests many ways to pretest the reliability of a questionnaire. Krosnick (1999) outlines three ways of pretesting for reliability: 1) field testing, 2) behavior coding, and 3) cognitive pretesting. Fowler (1995) has also included focus group discussions as a mode of pretesting survey questionnaires. In field testing, interviewers conduct actual interviews in a limited number of cases and discuss their experience to identify potential problems encountered in understanding questions, difference in respondent's and the researcher's understanding, and other issues. More recently, researchers have used behavior coding where pretest interviews are monitored by observers searching for physical or other cues to ascertain the robustness of a particular question or the questionnaire. Cognitive pretesting involves verbal protocol, where

respondents are made to think aloud as they go through the questionnaire. That provides a basis to ascertain whether the researcher's assumptions are valid or if the questionnaire needs changes. Focus group discussions, according to Fowler (1995), helps in developing a deeper understanding of the reality regarding which questions are being asked, as well as the researcher's assumptions about vocabulary used in the questionnaire. As Krosnick (1999) points out, the three options provide different type of testing support.

Respondent's or interviewer's difficulties, or problems, are more readily detected in behavior coding. Cognitive coding is more focused on respondent difficulties and is more appropriate in understanding confusions and misunderstandings faced by respondent going through the questions.

Two types of pretesting were done in this study. Since the interviewer in this study was one person (the investigator), the issue of respondent's difficulties was of more importance. The questionnaire was subjected to cognitive testing with four participants. The participants were encouraged to think aloud and let the investigator know how they interpret questions, the appropriateness of answer choices and other issues. A separate testing was conducted using an actual courtroom user (more akin to field testing). The primary focus in the second testing was to ascertain if the wordings used in the questions (judicial as well as technical) are appropriate, and if clarity is a problem in any question in the questionnaire. As compared to a social survey or surveys in other domains, possibilities of ambiguity in vocabulary in this study arises more from architectural and judicial jargons. Technical, architectural terms could lead to faulty understanding on the part of the respondent. Similarly, the investigator possesses comparatively limited knowledge of judicial vocabulary, and such terms used in the questionnaire needed to be

tested. Pretesting with the five respondents resulted in several changes to wordings before the questionnaire was finalized.

5.4 Testing for Validity

Fowler (1993) aptly points out that for subjective questions, as opposed to factual data questions, estimating validity of a measure is a difficult issue. He, however, suggests three ways in which to increase or assure the validity of data gathered. The first suggestion is to make the questions as reliable as possible. The second suggestion is to increase the number of scale points (response choices) as much as possible without losing semantics of the text labels. The third suggestion is to ask multiple questions for each topic addressed in the questionnaire. The first two suggestions, and actions on it, have been discussed in the sections above. Creating multiple questions for assessing environmental support to task performance would not have been possible within the page length that was being targeted. The first two steps, it is assumed, provides sufficient validity to the data collected.

Appendix VI

6.1 Data Distribution

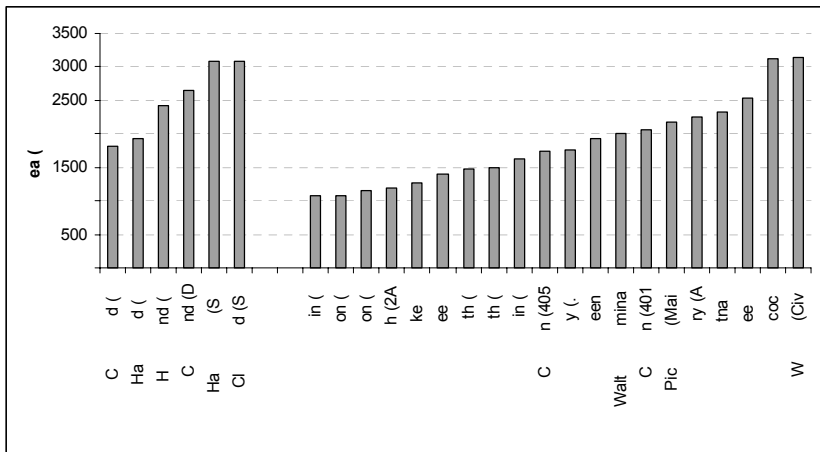


Figure VI.1: Courtroom area (sq.ft) of federal (left) and state (right) courtrooms in the database.

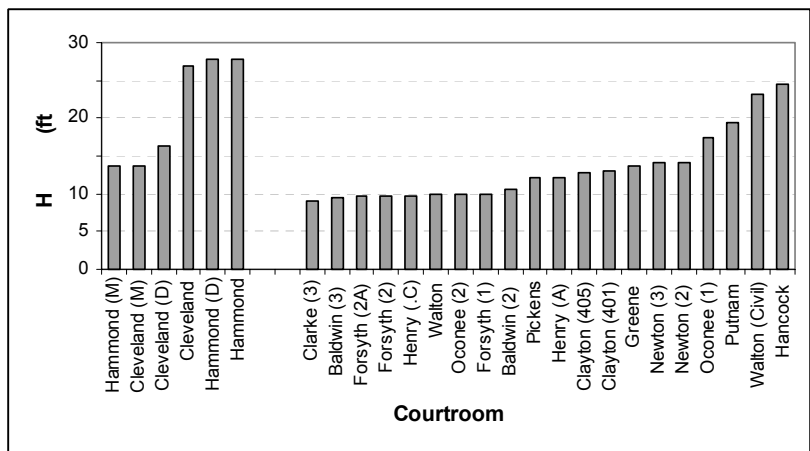


Figure VI.2: Courtroom height (ft.) of federal (left) and state (right) courtrooms in the database.

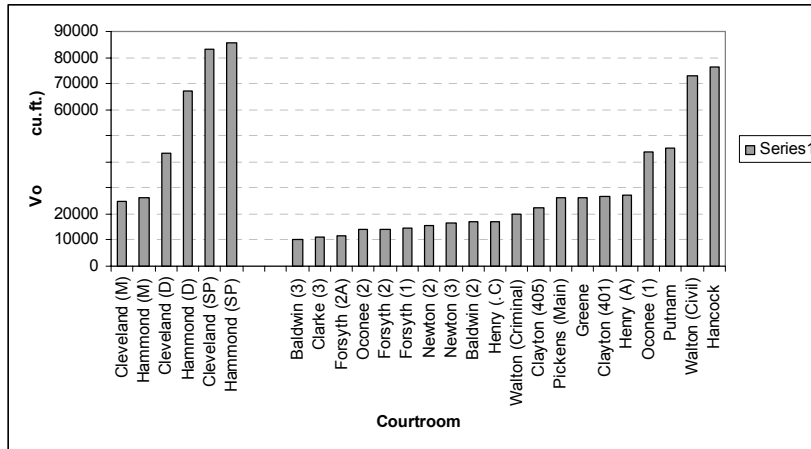


Figure VI.3: Courtroom volume (cu.ft.) of federal (left) and state (right) courtrooms in the database.

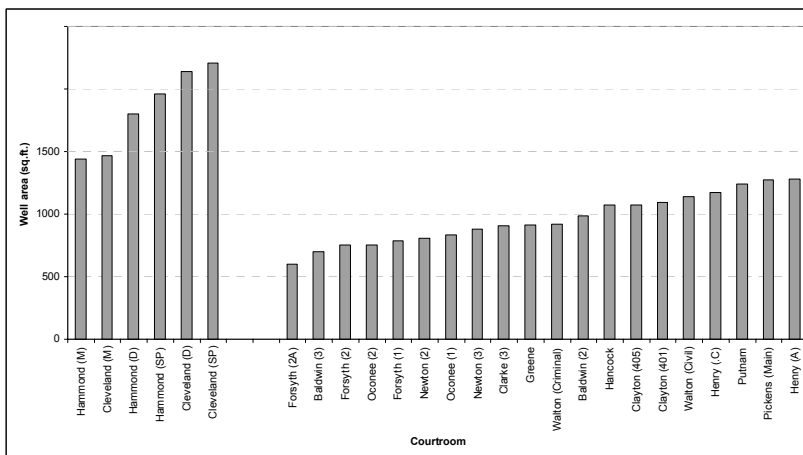


Figure VI.4: Well area (sq.ft.) of federal (left) and state (right) courtrooms in the database.

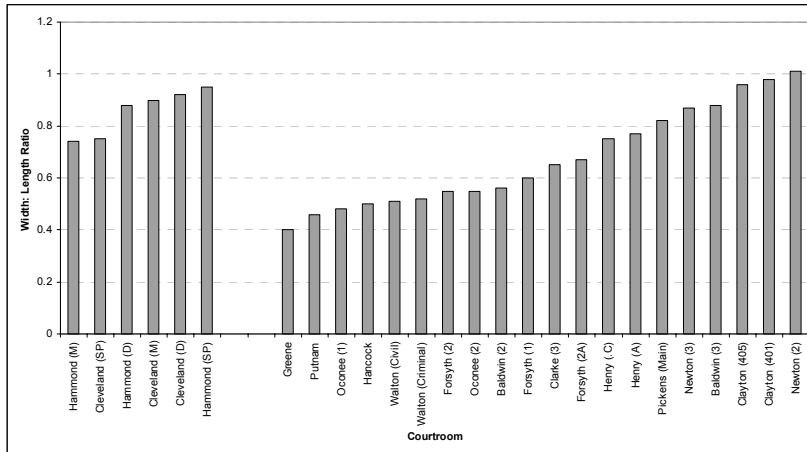


Figure VI.5: Width: Length ratio of courtroom well in federal (left) and state (right) courtrooms.

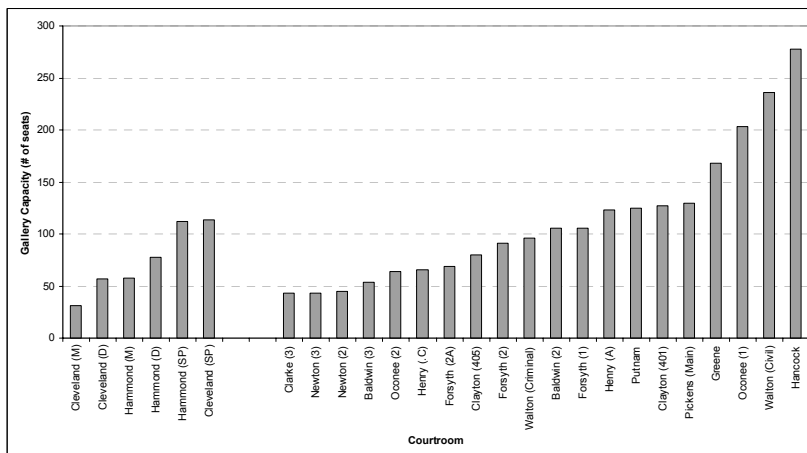


Figure VI.6: Gallery seating capacity in federal (left) and state (right) courtroom.

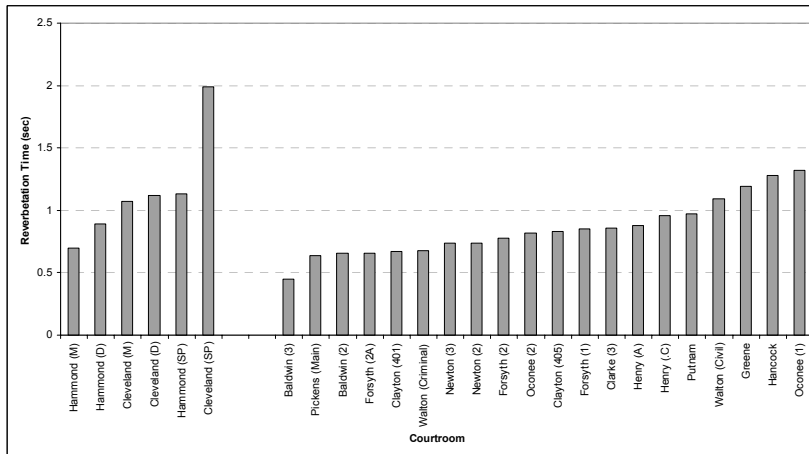


Figure VI.7: Reverberation time in federal (left) and state (right) courtrooms.

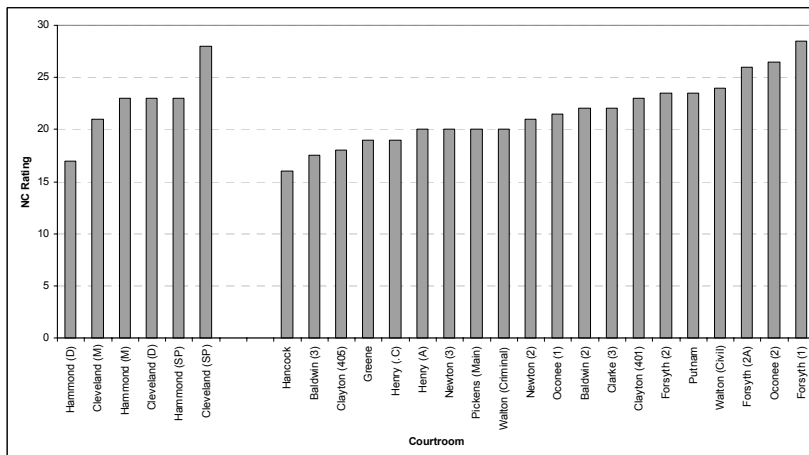


Figure VI.8: Background Noise (NC Ratings) in federal (left) and state (right) courtrooms.

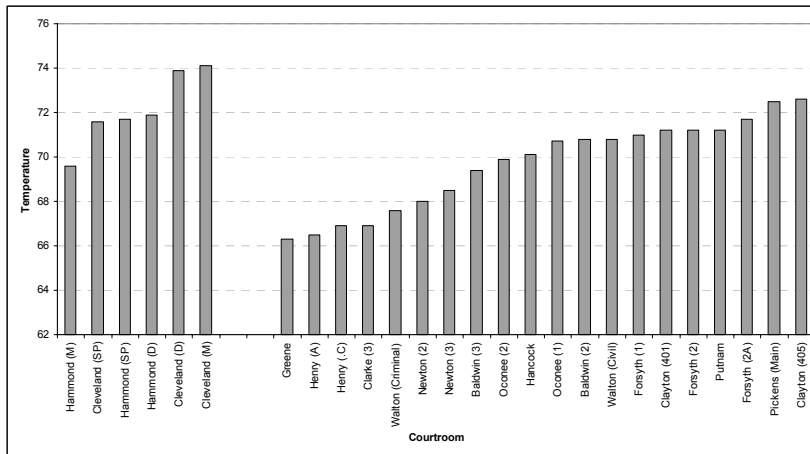


Figure VI.9: Temperature (measured between August – October) in federal (left) and state (right) courtrooms in the database.

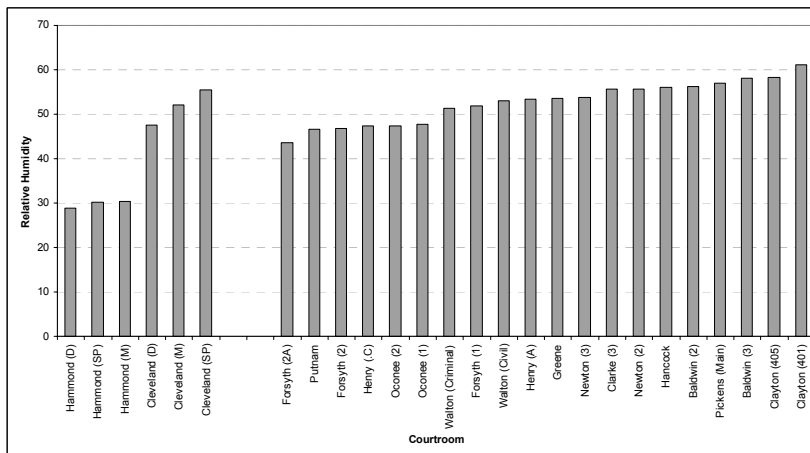


Figure VI.10: Relative humidity (measured between August – October) in federal (left) and state (right) courtrooms in the database.

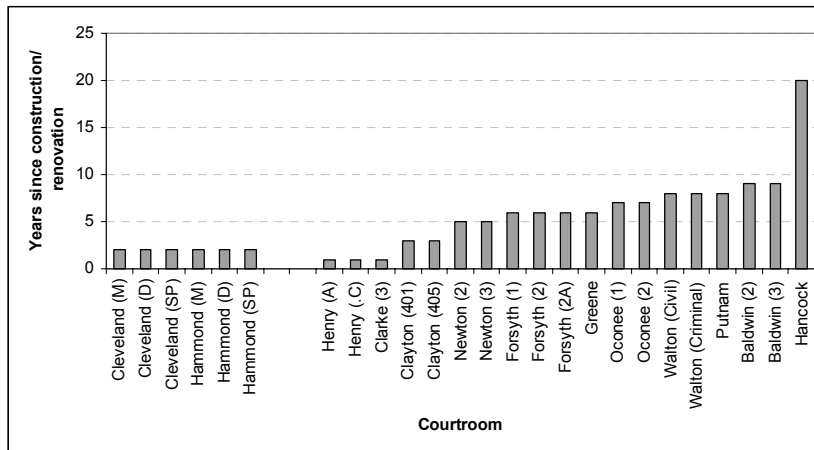


Figure VI.11: Years of occupation since construction or last renovation of federal (left) and state (right) courtrooms in the database.

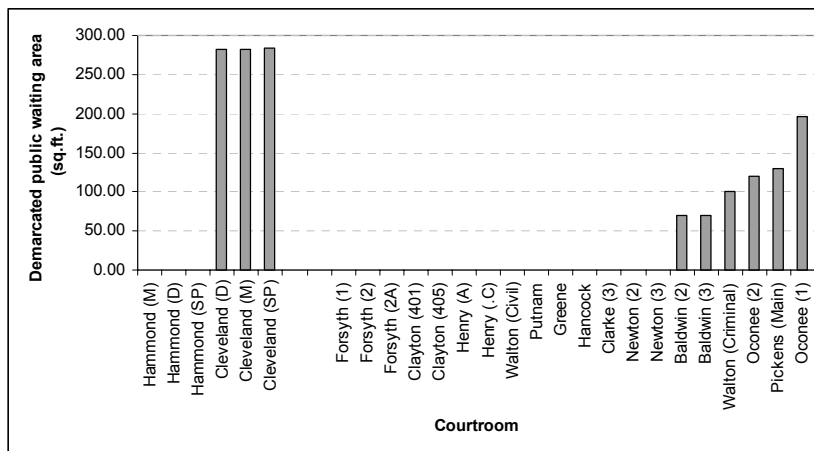


Figure VI.12: Demarcated public waiting area (sq.ft.), if any, in federal (left) and state (right) courtrooms.

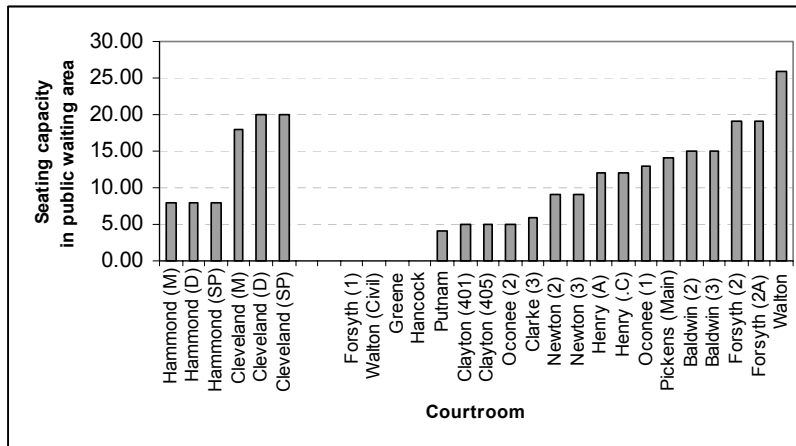


Figure VI.13: Number of seats in public waiting areas in federal (left) and state (right) courtrooms in the.

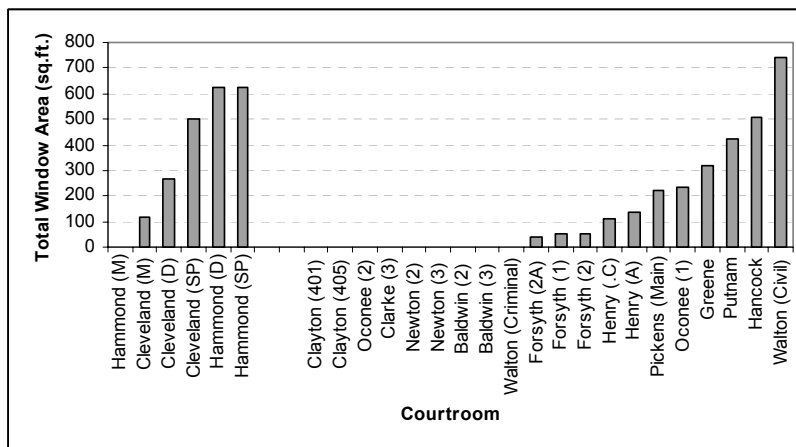


Figure VI.14: Total area in windows (sq.ft.) in federal (left) and state (right) courtrooms.

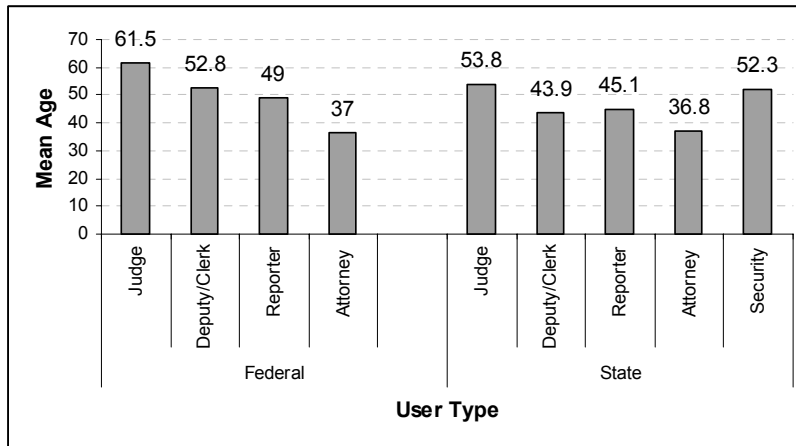


Figure VI.15: Mean age of users in federal (left) and state (right) courtrooms.

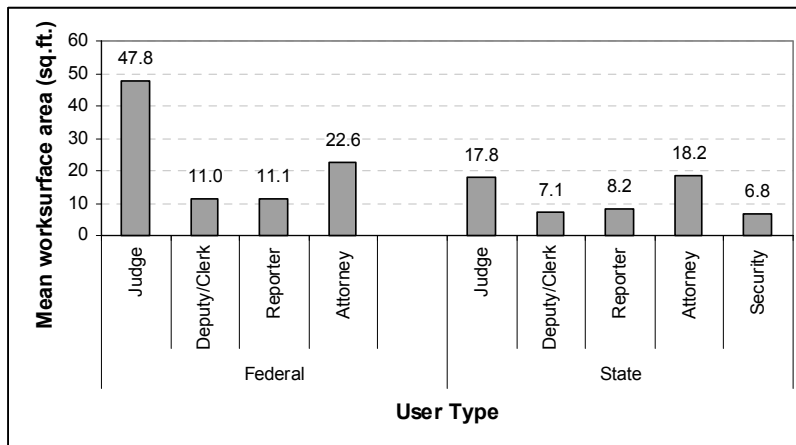


Figure VI.16: Mean work surface area (sq.ft.) of users in federal (left) and state (right) courtrooms.

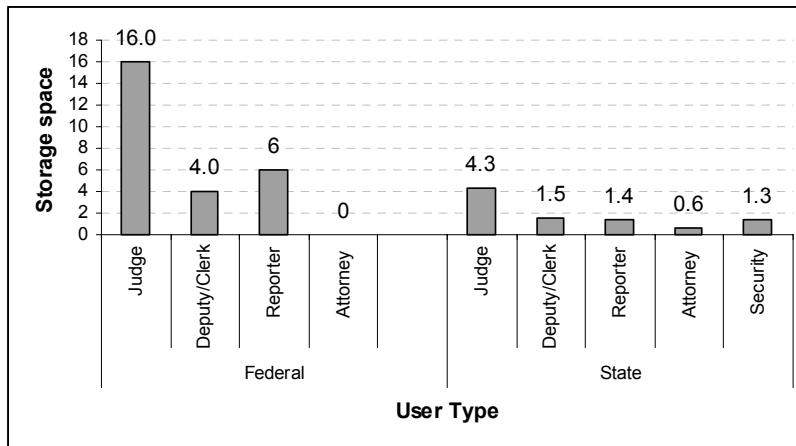


Figure VI.17: Mean storage space (linear ft.) at workstations in federal (left) and state (right) courtrooms.

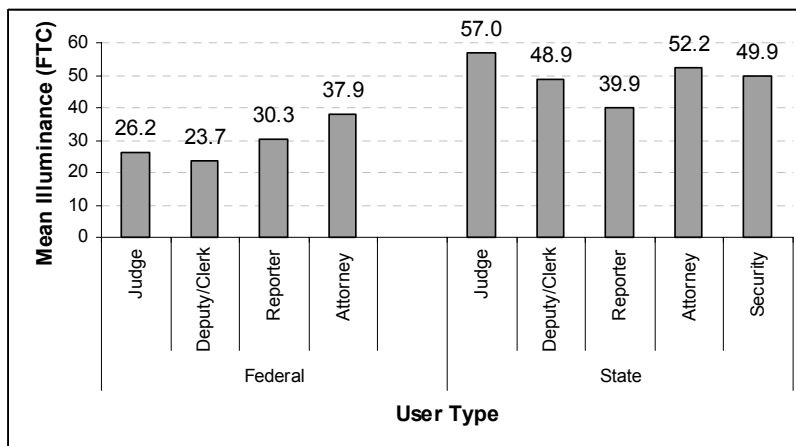


Figure VI.18: Mean illuminance on work plane (FTC) in federal (left) and state (right) courtrooms.

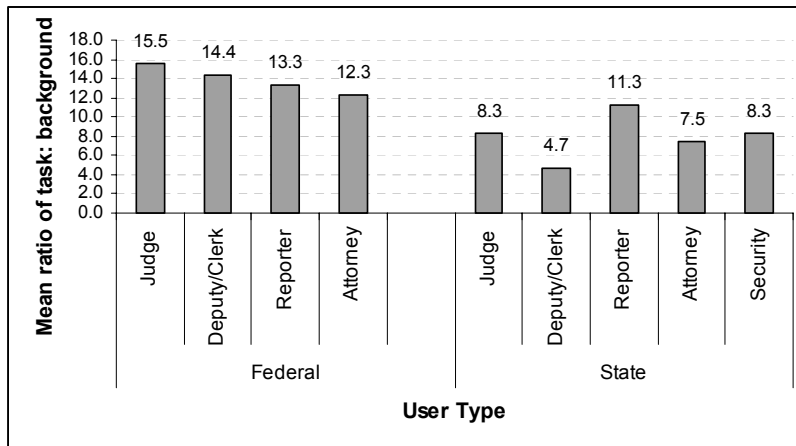


Figure VI.19: Mean ratio of task: background luminance in federal (left) and state (right) courtrooms.

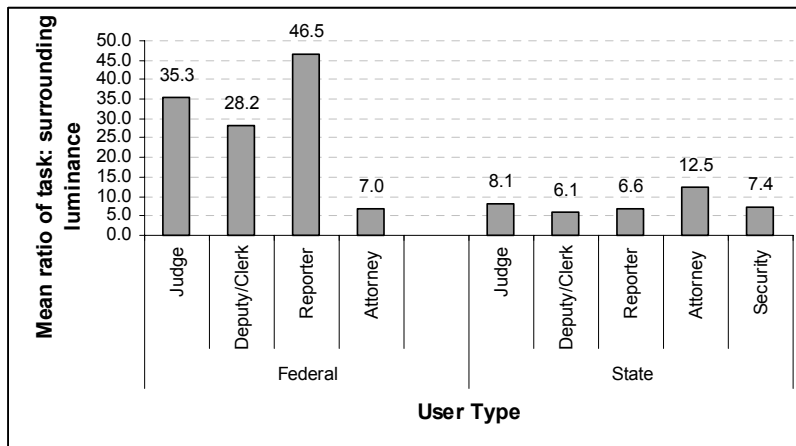


Figure VI.20: Mean ratio of task: surrounding luminance in federal (left) and state (right) courtrooms.

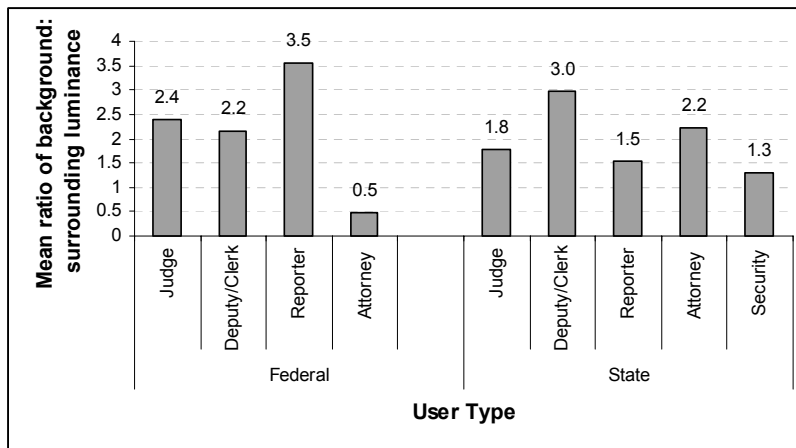


Figure VI.21: Mean ratio of background: surrounding luminance in federal (left) and state (right) courtrooms.

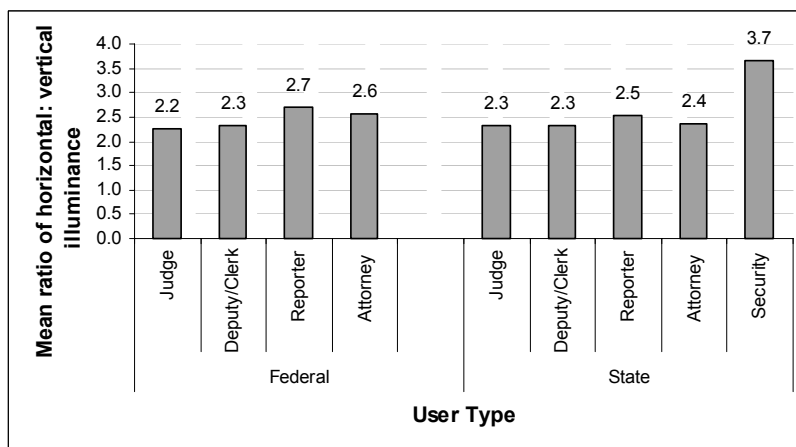


Figure VI.22: Mean ratio of horizontal: vertical illuminance in federal (left) and state (right) courtrooms.

6.2 Summary of multilevel regression models

Table VI.1: Model summary for regression involving Near Visual tasks (sample size: 852)

| R | R² | Adjusted R² | F | Significance |
|---------------------|-----------------------------------|---------------------------------|----------|---------------------|
| .815 | .665 | .651 | 49.218 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 5.604 | | 36.045 | .000*** |
| work ill | .025 | .389 | 6.545 | .000*** |
| task bkg | .024 | .121 | 2.940 | .003** |
| task sur | .034 | .369 | 3.139 | .002** |
| bkgr sur | -.720 | -.1301 | -9.191 | .000*** |
| max task | .018 | .349 | 5.661 | .000*** |
| window a | -.003 | -.484 | -4.346 | .000*** |
| age | -.046 | -.379 | -10.058 | .000*** |
| gender | -.638 | -.234 | -7.228 | .000*** |
| occupied | -.217 | -.744 | -5.136 | .000*** |
| role 1 | -.126 | -.042 | -1.182 | .237 |
| role 2 | -.704 | -.207 | -4.921 | .000*** |
| role 3 | -.827 | -.254 | -5.168 | .000*** |
| window_a x work ill | -7.171E-05 | -.261 | -4.042 | .000*** |
| window_a x task bkg | .000 | -.255 | -6.458 | .000*** |
| window_a x task sur | .001 | 1.082 | 12.333 | .000*** |
| window_a x bkgr sur | -.004 | -1.333 | -10.399 | .000*** |
| window_a x max task | .000 | -.816 | -9.468 | .000*** |
| window_a x age | .000 | -.287 | -7.014 | .000*** |
| window_a x gender | .001 | .137 | 3.439 | .001*** |
| window_a x role 1 | -.002 | -.166 | -3.484 | .001*** |
| window_a x role 2 | .000 | -.036 | -.553 | .580 |
| window_a x role 3 | -.002 | -.190 | -3.214 | .001*** |
| occupied x work ill | .002 | .120 | 1.765 | .078+ |
| occupied x task bkg | -.002 | -.029 | -.451 | .652 |

Table VI.1 (continued)

| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
|---------------------|----------------------------|--------------------------|--------|--------------|
| occupied x task sur | -.002 | -.110 | -.978 | .328 |
| occupied x bkgr sur | -.057 | -.421 | -4.345 | .000*** |
| occupied x max task | .004 | .759 | 8.621 | .000*** |
| occupied x age | -.008 | -.285 | -7.731 | .000*** |
| occupied x gender | .066 | .141 | 3.300 | .001*** |
| occupied x role 1 | -.028 | -.032 | -.719 | .473 |
| occupied x role 2 | -.149 | -.313 | -4.439 | .000*** |
| occupied x role 3 | .002 | .002 | .041 | .967 |
| occupied x role-4 | -.334 | -.044 | -1.899 | .058+ |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.2: Model summary for regression involving Near Visual screen tasks (sample size: 999)

| R | | Adjusted R² | F | Significance |
|------------------------|-----------------------------------|---------------------------------|----------|---------------------|
| .631 | | .398 | 28.08 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | | Significance |
| (Constant) | 5.667 | | 41.229 | .000*** |
| scrn ill | .015 | .060 | .905 | .366 |
| srn bkgr | -.422 | -.026 | -.301 | .763 |
| srn surr | -3.320 | -.319 | -2.159 | .031* |
| bkgr sur | -.175 | -.300 | -7.014 | .000*** |
| max task | .007 | .119 | 2.985 | .003** |
| age | -.032 | -.239 | -7.250 | .000*** |
| gender | -.337 | -.118 | -3.363 | .001** |
| occupied | -.147 | -.471 | -4.927 | .000*** |
| role 1 | -.418 | -.132 | -3.535 | .000*** |
| role 2 | -.683 | -.191 | -5.128 | .000*** |
| role 3 | -.715 | -.201 | -4.732 | .000*** |
| role 4 | .044 | .007 | .242 | .809 |
| occupied x scrn ill | .006 | .095 | 1.250 | .212 |
| occupied x srn bkgr | -.058 | -.015 | -.153 | .878 |
| occupied x srn surr | -.725 | -.330 | -2.416 | .016* |
| occupied x bkgr sur | -.036 | -.238 | -4.910 | .000*** |
| occupied x max task | .001 | .148 | 2.319 | .021* |
| occupied x age | -.010 | -.338 | -8.949 | .000*** |
| occupied x gender | -.005 | -.011 | -.203 | .839 |
| occupied x role 1 | -.183 | -.193 | -4.761 | .000*** |
| occupied x role 2 | -.150 | -.277 | -4.851 | .000*** |
| occupied x role 3 | -.356 | -.319 | -7.828 | .000*** |
| occupied x role 4 | -.072 | -.059 | -1.577 | .115 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.3: Model summary for regression involving physical variables and Near Visual tasks (sample size: 852).

| R | R² | Adjusted R² | F | Significance |
|---------------------|-----------------------------------|---------------------------------|----------|---------------------|
| .74 | .55 | .44 | 63.229 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 6.097 | | 59.614 | .000*** |
| work len | -.303 | -.905 | -10.719 | .000*** |
| work dep | -.091 | -.028 | -.623 | .534 |
| age | -.047 | -.389 | -12.375 | .000*** |
| gender | -.391 | -.143 | -4.781 | .000*** |
| occupied | .104 | .358 | 4.442 | .000*** |
| role 1 | -1.305 | -.432 | -9.334 | .000*** |
| role 2 | -1.112 | -.326 | -7.183 | .000*** |
| role 3 | -.933 | -.286 | -5.313 | .000*** |
| occupied x work len | -.102 | -1.192 | -13.815 | .000*** |
| occupied x work dep | -.060 | -.057 | -1.210 | .227 |
| occupied x age | -.011 | -.393 | -10.951 | .000*** |
| occupied x gender | -.002 | -.004 | -.102 | .919 |
| occupied x role 1 | -.627 | -.714 | -17.012 | .000*** |
| occupied x role 2 | -.477 | -1.001 | -12.559 | .000*** |
| occupied x role 3 | -.517 | -.500 | -10.649 | .000*** |
| occupied x role 4 | -.186 | -.024 | -.916 | .360 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.4: Model summary for regression involving Far Visual tasks (sample size: 852)

| R | R² | Adjusted R² | F | Significance |
|---------------------|-----------------------|-------------------------------|----------|---------------------|
| .726 | .527 | .511 | 32.814 | .000*** |
| Variable | Unstandardized | Standardized | t | Significance |
| (Constant) | 4.991 | | 56.170 | .000*** |
| hor verw | -.335 | -.395 | -7.295 | .000*** |
| hor verg | -.120 | -.111 | -2.098 | .036* |
| surr cei | .209 | 1.164 | 7.005 | .000*** |
| age | -.013 | -.195 | -5.956 | .000*** |
| occupied | -.089 | -.566 | -4.776 | .000*** |
| cr_area | .000 | .180 | 1.462 | .144 |
| sight ob | .014 | .147 | 2.581 | .010** |
| role_1 | -.046 | -.028 | -.690 | .491 |
| role_2 | -.289 | -.158 | -3.963 | .000*** |
| role_3 | .057 | .032 | .545 | .586 |
| occupied x hor verw | -.096 | -.261 | -5.437 | .000*** |
| occupied x hor verg | -.026 | -.170 | -1.797 | .073+ |
| occupied x surr cei | -.012 | -.780 | -1.895 | .058+ |
| occupied x age | -.005 | -.338 | -8.806 | .000*** |
| occupied x sight ob | .000 | .007 | .118 | .906 |
| occupied x role_1 | .124 | .262 | 5.144 | .000*** |
| occupied x role_2 | .090 | .351 | 4.147 | .000*** |
| occupied x role_3 | -.045 | -.080 | -1.335 | .182 |
| occupied x role_4 | 2.088 | .506 | .970 | .333 |
| cr_area x hor verw | .000 | -.289 | -6.482 | .000*** |
| cr_area x hor verg | .000 | .165 | 3.085 | .002** |
| cr_area x surr cei | 3.880E-05 | .235 | .810 | .418 |
| cr_area x age | 7.347E-08 | .001 | .019 | .985 |
| cr_area x sight ob | 5.188E-06 | .031 | .537 | .591 |
| cr_area x role_1 | .000 | .063 | 1.252 | .211 |
| cr_area x role_2 | .000 | -.190 | -3.161 | .002** |
| cr_area x role_3 | -.001 | -.243 | -3.847 | .000*** |
| cr_area x role_4 | -.003 | -.520 | -.991 | .322 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.5: Model summary for regression involving conversation tasks (sample size: 852).

| R | R² | Adjusted R² | Significance | |
|---------------------|-----------------------------------|-------------------------------|---------------------|---------------------|
| .787 | .619 | .606 | 46.184 | .000*** |
| Variable | Unstandardized Coefficient | S Coefficient | t | Significance |
| (Constant) | 6.871 | | 52.376 | .000*** |
| r time | 6.396 | 1.081 | 9.321 | .000*** |
| nc lvl | -.311 | -.640 | -5.471 | .000*** |
| sight ob | .152 | .742 | 9.696 | .000*** |
| occupied | .235 | .693 | 7.020 | .000*** |
| age | -.038 | -.269 | -7.241 | .000*** |
| gender | .064 | .020 | .603 | .547 |
| role 1 | -1.186 | -.337 | -8.947 | .000*** |
| role 2 | -1.823 | -.459 | -12.685 | .000*** |
| role 3 | -.914 | -.241 | -5.728 | .000*** |
| r time x sight ob | .887 | .867 | 12.038 | .000*** |
| r time x age | -.161 | -.318 | -6.897 | .000*** |
| r time x gender | .148 | .017 | .324 | .746 |
| r time x role 1 | -8.659 | -.769 | -11.074 | .000*** |
| r time x role 2 | -6.270 | -.405 | -8.787 | .000*** |
| r time x role 3 | -5.179 | -.281 | -6.291 | .000*** |
| nc lvl x sight ob | -.028 | -.601 | -12.842 | .000*** |
| nc lvl x age | .013 | .295 | 7.266 | .000*** |
| nc lvl x gender | -.083 | -.115 | -1.734 | .083+ |
| nc lvl x role 1 | .563 | .540 | 10.655 | .000*** |
| nc lvl x role 2 | .230 | .209 | 3.434 | .001*** |
| nc lvl x role 3 | .573 | .542 | 8.151 | .000*** |
| nc lvl x role 4 | -.202 | -.027 | -.444 | .657 |
| occupied x sight ob | .036 | .561 | 10.474 | .000*** |
| occupied x age | -.009 | -.252 | -7.239 | .000*** |
| occupied x gender | -.019 | -.035 | -.830 | .407 |
| occupied x role 1 | -.502 | -.490 | -9.275 | .000*** |
| occupied x role 2 | -.298 | -.536 | -9.072 | .000*** |
| occupied x role 3 | -.296 | -.245 | -5.891 | .000*** |
| occupied x role 4 | .242 | .027 | .444 | .657 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.6: Model summary for regression involving speech privacy (sample size: 892).

| R | R² | Adjusted R² | F | Significance |
|-------------------|-----------------------|-------------------------------|----------|---------------------|
| .682 | .465 | .448 | 27.847 | .000*** |
| Variable | Unstandardized | Standardized | t | Significance |
| (Constant) | 3.843 | | 27.336 | .000*** |
| r time | -2.795 | -.423 | -3.978 | .000*** |
| nc lvl | -.376 | -.692 | -6.303 | .000*** |
| occupied | -.371 | -.987 | -11.685 | .000*** |
| age | .000 | .003 | .072 | .943 |
| gender | .427 | .121 | 3.376 | .001*** |
| role 1 | 1.053 | .263 | 6.883 | .000*** |
| role 2 | 1.517 | .335 | 8.266 | .000*** |
| role 3 | .596 | .138 | 2.953 | .003** |
| role 4 | 2.182 | .309 | 7.451 | .000*** |
| r time x age | .132 | .239 | 4.496 | .000*** |
| r time x gender | 4.197 | .452 | 7.334 | .000*** |
| r time x role 1 | 1.980 | .153 | 2.815 | .005** |
| r time x role 2 | .772 | .043 | .850 | .395 |
| r time x role 3 | 8.957 | .424 | 9.265 | .000*** |
| r time x role 4 | 4.868 | .182 | 3.748 | .000*** |
| nc lvl x age | .003 | .064 | 1.561 | .119 |
| nc lvl x gender | -.019 | -.024 | -.356 | .722 |
| nc lvl x role 1 | .274 | .229 | 5.278 | .000*** |
| nc lvl x role 2 | .337 | .267 | 4.507 | .000*** |
| nc lvl x role 3 | .430 | .355 | 5.521 | .000*** |
| nc lvl x role 4 | -.092 | -.037 | -.835 | .404 |
| occupied x age | .000 | -.013 | -.305 | .760 |
| occupied x gender | .234 | .409 | 8.128 | .000*** |
| occupied x role 1 | .122 | .104 | 2.443 | .015* |
| occupied x role 2 | .323 | .507 | 8.190 | .000*** |
| occupied x role 3 | .314 | .227 | 5.634 | .000*** |
| occupied x role-4 | -.248 | -.173 | -3.087 | .002** |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.7: Model summary for regression involving well size (sample size: 866).

| R | R² | Adjusted R² | F | Significance |
|-------------------|-----------------------------------|---------------------------------|----------|---------------------|
| .791 | .626 | .614 | 52.068 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 6.356 | | 56.927 | .000*** |
| well len | .147 | .558 | 6.987 | .000*** |
| well wid | -.022 | -.094 | -1.291 | .197 |
| age | .002 | .010 | .336 | .737 |
| gender | -1.109 | -.327 | -11.295 | .000*** |
| occupied | .117 | .323 | 3.359 | .001*** |
| role 1 | -.441 | -.114 | -3.834 | .000*** |
| role 2 | .039 | .009 | .270 | .787 |
| role 3 | -2.407 | -.586 | -14.228 | .000*** |
| role 4 | .064 | .010 | .324 | .746 |
| well len x age | -.004 | -.174 | -3.978 | .000*** |
| well len x gender | -.013 | -.035 | -.739 | .460 |
| well len x role 1 | -.041 | -.077 | -1.715 | .087+ |
| well len x role 2 | -.119 | -.193 | -5.149 | .000*** |
| well len x role 3 | -.297 | -.452 | -8.549 | .000*** |
| well len x role 4 | .223 | .094 | 2.120 | .034* |
| well wid x age | .002 | .069 | 2.042 | .041* |
| well wid x gender | .064 | .187 | 3.883 | .000*** |
| well wid x role 1 | .020 | .042 | 1.037 | .300 |
| well wid x role 2 | .022 | .035 | 1.021 | .308 |
| well wid x role 3 | .323 | .475 | 11.795 | .000*** |
| well wid x role-4 | .100 | .151 | 4.273 | .000*** |
| occupied x age | -.010 | -.264 | -5.452 | .000*** |
| occupied x gender | .000 | -.001 | -.014 | .989 |
| occupied x role 1 | .012 | .010 | .247 | .805 |
| occupied x role 2 | -.200 | -.323 | -4.662 | .000*** |
| occupied x role 3 | -.537 | -.411 | -9.376 | .000*** |
| occupied x role-4 | -.133 | -.098 | -2.136 | .033* |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.8: Model summary for regression involving well shape (sample size: 961).

| R | R² | Adjusted R² | F | Significance |
|-------------------|-----------------------------------|---------------------------------|----------|---------------------|
| .319 | .102 | .088 | 7.662 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 5.486 | | 61.750 | .000*** |
| well_shp | 1.841 | .217 | 3.484 | .001*** |
| occupied | -.066 | -.192 | -3.446 | .001*** |
| role_1 | -.239 | -.068 | -1.815 | .070+ |
| role_2 | .113 | .027 | .732 | .465 |
| role_3 | -.667 | -.172 | -4.307 | .000*** |
| role_4 | .377 | .058 | 1.481 | .139 |
| well_shp x role_1 | .855 | .051 | .997 | .319 |
| well_shp x role_2 | -.860 | -.044 | -.960 | .337 |
| well_shp x role_3 | -2.929 | -.128 | -2.859 | .004** |
| well_shp x role-4 | -2.576 | -.090 | -2.248 | .025* |
| occupied x role_1 | .227 | .202 | 4.535 | .000*** |
| occupied x role_2 | .068 | .112 | 2.288 | .022* |
| occupied x role_3 | -.157 | -.130 | -2.869 | .004** |
| occupied x role-4 | -.027 | -.020 | -.471 | .638 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.9 : Model summary for regression involving gallery capacity (sample size: 975).

| R | R² | Adjusted R² | F | Significance |
|--|-----------------------------------|---------------------------------|----------|---------------------|
| .579 | .336 | .326 | 34.703 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 5.338 | | 57.606 | .000*** |
| gal seat | .020 | .717 | 9.095 | .000*** |
| occupied | -.241 | -.578 | -8.269 | .000*** |
| role 1 | -.329 | -.078 | -2.389 | .017* |
| role 2 | -.090 | -.018 | -.560 | .576 |
| role 3 | -.740 | -.157 | -4.724 | .000*** |
| role 4 | 1.114 | .141 | 2.870 | .004** |
| gal seat x role 1 | .000 | .005 | .125 | .901 |
| gal seat x role 2 | -.008 | -.165 | -2.533 | .011* |
| gal seat x role 3 | .003 | .044 | 1.021 | .308 |
| gal seat x role 4 | .026 | .237 | 3.455 | .001*** |
| occupied x role 1 | .037 | .029 | .769 | .442 |
| occupied x role 2 | .170 | .231 | 3.716 | .000*** |
| occupied x role 3 | .269 | .182 | 4.571 | .000*** |
| occupied x role-4 | -.489 | -.303 | -3.952 | .000*** |
| *** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1) | | | | |

Table VI.10: Model summary for regression involving public waiting area (sample size: 975).

| R | R² | Adjusted R² | Significance | |
|--|-----------------------------------|-------------------------------|---------------------|---------------------|
| 470 | .221 | .210 | 19.474 | .000*** |
| Variable | Unstandardized Coefficient | S Coefficient | t | Significance |
| (Constant) | 4.738 | | 42.907 | .000*** |
| wait are | .002 | .077 | 1.609 | .108 |
| occupied | .021 | .047 | 1.007 | .314 |
| role 1 | -.392 | -.085 | -2.411 | .016* |
| role 2 | -.900 | -.164 | -4.710 | .000*** |
| role 3 | -1.837 | -.355 | -9.830 | .000*** |
| role 4 | -1.249 | -.144 | -3.343 | .001*** |
| wait are x role 1 | .008 | .173 | 4.454 | .000*** |
| wait are x role 2 | .007 | .132 | 3.501 | .000*** |
| wait are x role 3 | .010 | .130 | 3.464 | .001*** |
| wait are x role 4 | -.021 | -.105 | -2.734 | .006** |
| occupied x role 1 | -.167 | -.121 | -3.609 | .000*** |
| occupied x role 2 | -.048 | -.060 | -1.436 | .151 |
| occupied x role 3 | -.433 | -.267 | -6.958 | .000*** |
| occupied x role-4 | -.038 | -.022 | -.628 | .530 |
| *** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1) | | | | |

Table VI.11: Model summary for regression involving public waiting capacity (sample size: 960).

| R | R² | Adjusted R² | F | Significance |
|-------------------|-----------------------------------|---------------------------------|----------|---------------------|
| 460 | .212 | .200 | 18.178 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | Significance |
| (Constant) | 4.483 | | 39.711 | .000*** |
| wait_cap | .006 | .022 | .377 | .706 |
| occupied | -.044 | -.097 | -1.967 | .050* |
| role_1 | -.227 | -.050 | -1.330 | .184 |
| role_2 | -.339 | -.063 | -1.664 | .096+ |
| role_3 | -1.903 | -.373 | -10.105 | .000*** |
| role_4 | -.656 | -.077 | -2.213 | .027* |
| wait_cap x role_1 | .038 | .075 | 1.702 | .089+ |
| wait_cap x role_2 | .129 | .192 | 4.098 | .000*** |
| wait_cap x role_3 | -.061 | -.092 | -2.418 | .016* |
| wait_cap x role-4 | -.060 | -.038 | -1.091 | .275 |
| occupied x role_1 | -.132 | -.098 | -2.810 | .005** |
| occupied x role_2 | -.023 | -.029 | -.631 | .528 |
| occupied x role_3 | -.105 | -.066 | -1.857 | .064+ |
| occupied x role-4 | .020 | .012 | .300 | .765 |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Table VI.12: Model summary for regression involving courtroom symbolism (sample size:959).

| R | R² | d R² | F | |
|---------------------|-----------------------------------|---------------------------------|----------|---------|
| .838 | .702 | .694 | 81.447 | .000*** |
| Variable | Unstandardized Coefficient | Standardized Coefficient | t | |
| (Constant) | 5.195 | | 49.050 | .000*** |
| cr shape | -4.861 | -.885 | -13.635 | .000*** |
| cr symb | .552 | .447 | 3.525 | .000*** |
| ben symb | -.585 | -.456 | -9.613 | .000*** |
| jur symb | -3.512 | -1.329 | -13.618 | .000*** |
| gal seat | -.001 | -.068 | -.536 | .592 |
| hor verw | .330 | .261 | 8.024 | .000*** |
| hor verg | -.710 | -.404 | -3.693 | .000*** |
| surr cei | .416 | 1.347 | 4.266 | .000*** |
| surr flo | -.408 | -1.207 | -7.370 | .000*** |
| cr shape x hor verw | -.103 | -.015 | -.450 | .653 |
| cr shape x surr cei | -.685 | -.571 | -2.470 | .014* |
| cr shape x surr flo | -2.282 | -1.653 | -14.387 | .000*** |
| cr symb x hor verw | -.198 | -.113 | -2.615 | .009** |
| cr symb x surr cei | -1.012 | -4.970 | -7.196 | .000*** |
| cr symb x surr flo | .637 | 2.464 | 8.136 | .000*** |
| ben_symb x hor verw | .124 | .088 | 2.945 | .003* |
| ben symb x surr cei | .190 | .367 | 4.135 | .000*** |
| ben symb x surr flo | -.170 | -.306 | -4.072 | .000*** |
| jur_symb x hor verw | -.301 | -.097 | -3.812 | .000*** |
| jur symb x surr cei | -2.350 | -2.128 | -7.008 | .000*** |
| jur symb x surr flo | .893 | .919 | 4.035 | .000*** |
| gal seat x hor verw | .002 | .095 | 2.140 | .033* |
| gal seat x surr cei | .001 | .443 | .644 | .520 |
| gal seat x surr flo | .009 | 3.258 | 9.905 | .000*** |
| hor verg x hor verw | .095 | .034 | 1.427 | .154 |
| hor verg x surr cei | -.583 | -2.173 | -6.661 | .000*** |
| hor verg x surr flo | .155 | .444 | 1.669 | .095+ |

*** (significant at .001), ** (significant at 0.01), * (significant at 0.05), + (significant at 0.1)

Note: model demonstrates multicollinearity despite corrective measures; findings should be treated with caution.

6.3 End-user interface and automated querying



Figure VI.23: Picture of the working interface developed to demonstrate automated querying.

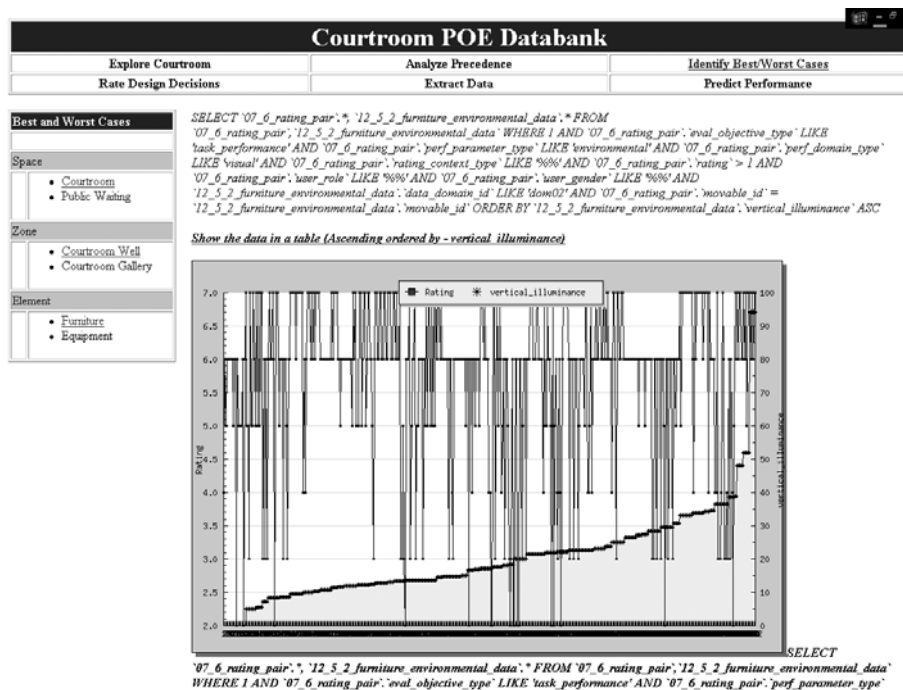


Figure VI.24: An example query result interface with link to query result table.

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